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IRRIGATION SECTOR REVIEW

Volume II - Supplementary Analysis

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Agriculture Operations Division
India Department
Asia Region

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Preface

This is the second volume to a two volume report on the Indian irrigation sector. The "Main Report" (Volume I) contains the full discussion and recommendations relative to the Irrigation Sector Review. This "Supplementary Analysis" (Volume II) report contains additional discussion and analysis in selected areas as back-up material for Volume I. Further background analysis is contained in a number of Irrigation Sector Review background papers (see Annex II of Volume I). The index for both Volumes I and II is included at the beginning of this report.

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IRRIGATION SECTOR REVIEW

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IRRIGATION SECTOR REVIEW

VOLUME II

(SUPPLEMENTARY ANALYSIS)

Chapter I: Irrigation Development and its Impact

A. Development of Irrigation

1.1 Historical Development. Irrigation in India has ancient roots. Amongst those developments for which some historical records exist, is the Grand Anicut in present day Tamil Nadu which was begun in the 2nd century AD with its basic design still used today. Some tanks used in southern India today are known to go back to before the 10th century, and construction of some of the Yamuna canals in Haryana began in the 14th century. Further development of irrigation took place in the British period starting in the first half of the 19th century with renovation and improvement of existing works and later with new investments. Development was further stimulated as a result of the great famine of 1876-78. By 1900 the total irrigated area in undivided India was about 13.4 million hectares of which 56% was under public schemes and the rest private, mainly wells and tanks. The two successive famines at the end of the 19th century led to increased attention to irrigation development and appointment of the First Irrigation Commission in 1901 which recommended an expanded public irrigation investment program and support for private irrigation investment through a combination of low interest loans, grants and survey assistance for location of wells. In reality, growth of private well irrigation showed only modest gains over the next 50 years but public irrigation (canals and public tubewells) expanded appreciably and by 1944-47 net irrigated area had expanded to 28.2 million hectares. Partition of India in 1947 resulted in a significant proportion of irrigated land passing over to Pakistan. In 1950-51, present day India's irrigation resource consisted of 20.9 million net hectares under irrigation (22.5 million hectares gross), of which 8 million hectares were irrigated by canals, 6.0 million hectares by wells and the remainder through tanks or other sources.

1.2 Development Since 1950. Independent India put major emphasis on irrigation development. From the 21 million hectares under irrigation in 1950, net irrigated area doubled to 42 million hectares in 1984-85, an expansion of about 0.6 million hectares per annum.[1] As shown in Table 1.1, the growth in net irrigated area has been due to two principal developments. Public investment in canal irrigation resulted in a doubling of the area under surface irrigation; from 8.3 to 15.9 million hectares between 1950-51 and 1984-85 or an annual expansion of about 220,000 hectares. Even more spectacular has been the growth of irrigation through tubewells, mainly private, which has expanded from minimal development through the early 1960s to 11.3 million hectares in 1984-85. Added to a more modest growth in the number of dugwells, the area irrigated by well irrigation was 20 million hectares in 1984-85, thus exceeding the 16 million hectares irrigated through canals. Particularly in northern India (especially the northwest) the development

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[1] Throughout this report, the terms "net" and "gross", when referring to irrigated or cropped area, utilize Indian rather than international nomenclature. In this report, "net irrigated area" refers to the land area that receives irrigation regardless of whether one or more irrigated crops are grown. "Gross irrigated area" refers to the total cropped area irrigated annually. Thus, where on a 1,000 hectare irrigated parcel of land 1.5 irrigated crops are grown per annum, net irrigated area is 1,000 ha and gross irrigated area is 1,500 ha.

of tubewell irrigation, supported by investment in electrification and provision of credit has been the main driving force behind irrigation expansion and productivity improvements over the past several decades. In contrast to the development of groundwater and canal irrigation, the net irrigated area under tanks or other sources of irrigation such as lift schemes has remained fairly constant and by 1984-85 represented only 14% of India's net irrigated area.

Table 1.1 Development of Irrigation: 1950 to 1985
(Net Irrigated Area in Million Hectares)

	1950-51	1960-61	1970-71	1980-81	1984-85
Canal Irrigation	8.3	10.4	12.8	15.3	15.9
Tanks	3.6	4.6	4.1	3.2	3.3
Tubewells	n/a	0.1	4.5	9.5	11.3
Other Wells	6.0	7.2	7.4	8.2	8.7
Other Sources	3.0	2.4	2.3	2.6	2.6
Total Net Irrigated Area	20.9	24.7	31.1	38.8	41.8

1.3 As shown in Table 1.2, about one third of gross cropped area in India is now irrigated. In the early 1950s only 17% of cultivated land was irrigated. As a result of the growth of irrigation, there have been a variety of impacts on agricultural production, incomes, regional development and poverty which will be discussed in this chapter.

Table 1.2 Share of Irrigation in Cultivated Areas

	Unit	1951/2	1965/66	1970/71	1984/85
Net Cropped Area	M ha	119.4	136.2	140.3	140.7
Gross Cropped Area	M ha	133.2	155.3	165.8	175.9
Area Cropped More Than Once	M ha	13.8	19.1	25.0	35.2
Net Irrigated Area	M ha	21.0	29.3	31.1	41.8
Gross Irrigated Area	M ha	23.2	30.9	38.2	54.1
Implied Irrigation Intensity	%	110	105	123	129
Share of Gross Irrigated to Gross Cropped Area	%	17.4	19.9	23.0	30.7

Data Source: Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi.

1.4 Data and Methodology. Analysis of irrigation's impact must contend with limitations in the available data. Most of the data used in the report pertain up to the mid 1980's for lack of more recent statistics.[2] Reported data is sometimes different depending on the official source used, as has been pointed out by numerous Government commissions on the subject. Most statistics are best regarded as approximate, and in some cases only indicative of the real situation, and some figures, as discussed where appropriate, may contain estimation biases due to the measurement sources available. A more important difficulty is the comparative rarity of reported data

[2] More recent data is available on financial matters and in some specific studies and has been used where available.

disaggregated between irrigated and unirrigated farming. Finally, analyses of irrigation impact have been beset by the tendency of many variables to vary in step with each other causing multicollinearity problems in regression analysis. Thus, uptake of irrigation is usually paralleled or followed by increased usage of fertilizer and high yielding varieties, increased use of capital and other developments. Similarly, regional differences in development of irrigation are often parallelled by similar differences in the state of development of other infrastructure and services (roads, markets, credit, education). Isolation of specific causes and effects have thus seldom been successful.

1.5 This chapter will develop the inferences that can be made about the impact of irrigation. An important simplifying procedure will be to regard irrigated agriculture, when compared to rainfed agriculture, as a package of farming technology changes enabled by irrigation. Irrigation is, thus, not the sole determinant of observed differences in, for instance, yields. However, the irrigation variable, by substantially changing the crop growing environment, enables intensification of input and labor use and, where effectively practiced, can have major impact on production and social development objectives.

B. Impact on Agricultural Production

Expansion of Cropped Area

1.6 India has now nearly reached the ceiling of available land suitable for cultivation. This is illustrated by the plateauing out of growth in reported net cropped area shown in Table 1.2. Until the mid 1960s, growth of net cropped area (still at 1% per annum between 1951 and 1965) remained a factor in India's agricultural growth. From 1970/71 to 1984/85, net cropped area hardly changed (from 140.3 to 140.7 million hectares). Agricultural growth in the past two decades has relied almost entirely on increasing productivity due to growth in crop yields (including crop substitution to higher value crops) and expansion of gross cropped area due to cropping more than once per annum on the same land. This latter influence has been quite significant. Gross cropped area expanded from 155 to 176 million hectares from 1965 to 1984, by 21 million hectares or at nearly 1% growth per annum.

1.7 The contribution of expansion of irrigation to increase in gross cropped area cannot be fully ascertained from the available data. Gross irrigated area expanded by 23.2 million hectares in the period 1965 to 1984. Since the overall net cropped area increased by only 4.5 million hectares, expansion of gross irrigated area was due either to irrigating already cropped but formerly rainfed land, or increasing cropping intensity on irrigated land. Assuming that the expansion by 12 million hectares in net irrigated land growing more than one crop per annum between 1965 and 1984 is entirely due to irrigation, then nearly 60% of the overall expansion of gross cropped area is from irrigation expansion. This is likely to overstate the area expansion impact of irrigation as part of the increase in double cropping would have occurred without irrigation, as has to some extent occurred on rainfed lands.[3]

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[3] The introduction of HYVs cropping technology on residual moisture has partly contributed to the increase in rainfed double cropping.

1.8 At the all India level, irrigation intensity (irrigation of more than one crop per annum expressed by the ratio of gross to net irrigated area) increased from 110% in 1950/51 to 129% in 1984/85. This has contributed to the growth in overall cropping intensity (including rainfed crops) which increased in the same period from 111% to 125%. The growth in cropping intensity has been quite variable between states mainly reflecting different rates of irrigation development, the kind of irrigation investment and rainfall distribution as illustrated in Table 1.3. Rapid development of irrigation in Haryana, Punjab and Uttar Pradesh has been accompanied by relatively high changes in cropping intensity; for instance, in Punjab from 127 to 161% or an increase of 34%, in two decades. The nature of the irrigation development in these northwest areas has had much to do with its impact on cropping intensity. Expansion of tubewells and availability of surface water from snow melt sources outside the monsoon season has enabled the growth of rabi and summer crops. Less impact from irrigation is found in areas where irrigation has been designed mainly as "supplemental" irrigation for the kharif (monsoon) crop based on run-of-the-river irrigation schemes without storage or replenishment from snow melt. Here, irrigation water is itself dependent on rainfall, and cropping intensity has not been greatly influenced by surface water irrigation, a common situation in eastern and central India. In Bihar, substantial growth of surface irrigation has had no apparent impact on cropping intensity.

Table 1.3 Changes in Irrigated Area and Cropping Intensity During 1960-63/1980-83 in Major States

		Rainfall (Normal) mm	Percent Net Sown Area Irrigated		Crop Intensity	
			1960-63	1980-83	1960-63	1980-83
1.	Low Rainfall Region					
	Punjab	590	53	82	127	161
	Haryana	610	32	62	133	149
	Rajasthan	500	13	20	108	116
	Gujarat	870	7	21	105	112
2.	Medium Rainfall Region					
	Maharashtra	870	6	11	105	110
	Andhra Pradesh	900	27	32	111	115
	Tamil Nadu*	990	41	48	121	124
	Karnataka	840	9	14	104	108
	Uttar Pradesh	1040	29	54	127	142
3.	High Rainfall Region					
	Madhya Pradesh	1140	6	12	113	114
	Bihar	1260	24	36	135	135
	West Bengal**		25	35	117	135
	Orissa	1450	16	20	112	141
4.	All India		19	28	115	124

* for 1979-80

** for 1983-84

Reported net and gross irrigated area are equal.

Source: Area and Production of Principal Crops, Ministry of Agriculture, GOI.

1.9 Various studies support the picture emerging from Table 1.3 but with somewhat different quantitative assessments of the impact of irrigation on cropping intensity. Narain and Roy (1980) using cross sectional analysis of statewide data concluded that a one percent increase in net irrigated area resulted in a 0.67 percent increase in crop intensity. They also found that cropping intensity was higher on smaller farms and that the impact of irrigation on cropping intensity was lower in higher rainfall areas. Dhawan's (1989) time series analysis led to the conclusion that a one percent increase in the percentage of gross irrigated to gross cropped area had resulted in a 0.62 percent increase in overall crop intensity. Rao et al (1988) found a much lower impact on cropping intensity from irrigation, but had similar conclusions to the above regarding regional differences in impact.

1.10 Future prospects for expanding gross crop area will depend upon the type of irrigation investments feasible. The following developments will have particularly strong impact on cropping intensities. First, the expansion of groundwater irrigation will continue to have a very positive impact. Second, storage schemes for irrigation outside the monsoon period will have much greater impact than irrigation using run-of-the river diversions. Third, irrigation investments that can provide some off-season water in drier regions would have greater impact on gross cropped area than in wetter eastern and central regions where somewhat longer monsoon periods and presence of residual moisture provide scope for second rainfed crops.

Crop Yields and Output

1.11 Available data and studies, although they vary in their assessment of impact depending on data sources used and analytical methodology, all indicate that productivity from irrigated lands is much higher than under rainfed conditions. Over 55% of gross agricultural output can be attributed to production from irrigation, though some estimates put these figures even higher. Yield differences are, however, very variable and in particular are influenced by rainfall levels and the nature and quality of individual irrigation systems.

1.12 The largest increments in yields are found in drier states with well functioning irrigation systems. Table 1.4 presents state level average yields for rice and wheat under irrigated and unirrigated conditions (1980-83). In Punjab, average yields of rice increase from 1 t/ha under rainfed conditions to 3 t/ha under irrigation, while wheat yields increase from 1.6 to 3 t/ha. Much lower impact is apparent in eastern and central India where rainfall is higher and the quality of the irrigation service is generally much lower. Monsoon waterlogging and lack of drainage further reduce the yield augmenting impact of irrigation in this region. Similar observations can be made from Table 1.5 based on Dhawan's analysis (1988) of yields of foodgrains taken as a whole and of all major crops expressed in terms of food energy equivalents. For India as a whole, Dhawan found that foodgrain yields in 1983-84 under irrigated conditions averaged 1980 kgs/ha as compared with rainfed yields of 864 kgs/ha, an increment of 1.1 t/ha or a 130% increase in productivity per hectare. Taking all crops into consideration, food energy equivalent yields were 2208 Kgs/ha compared with 877 Kgs/ha under rainfed conditions, up 1.3 tons or by 150%. The analysis by selected projects summarized in Table 1.6 provides some indication of the departures from state averages present at the level of individual irrigation schemes. Other studies point to similar conclusions regarding the yield impact of irrigation and its variability by region. Thus Vaidyanathan (1987), in an analysis of the impact of irrigation in 12 major states covering 12 crops for the 1974-75 to 1978-79 period estimated that the average value productivity per hectare of irrigated crops was about Rs. 1849, which is about 180% more compared to rainfed lands. There is a lower impact of irrigation in eastern and central India than in the drier states of the northwest and south (Annex Table 1.1).

Table 1.4 Irrigated and Unirrigated Yields of Rice and Wheat in Major States (1980-83)

State	Normal Rainfall (mm)	Rice (Autumn) Kgs/ha			Wheat Kgs/ha		
		Irrigated	Unirrigated	Percent Increase	Irrigated	Unirrigated	Percent Increase
1. Low Rainfall Regions							
Punjab	590	2957	1029	187	2960	1616	83
Haryana	610	-	-	-	2458	1644	50
Rajasthan	500	1737	613	183	1719	887	94
Gujarat	870	-	-	-	2506	510	391
2. Medium Rainfall Regions							
Maharashtra	870	n.a.	n.a.	-	1159	471	146
Andhra Pradesh	900	2115	920	130	-	-	-
Tamil Nadu	990	1880	401	369	-	-	-
Karnataka	840	1854	1460	27	1083	383	183
Uttar Pradesh	1040	1426	950	50	1176	1101	7
3. High Rainfall Regions							
Madhya Pradesh	1140	1143	758	51	1645	800	106
Bihar	1260	1552	704	120	1416	1020	39
West Bengal	n.a.	1522	873	78	-	-	-
Orissa	1450	922	670	38	-	-	-

Source: Area and Production of Principal Crops, GOI

TABLE 1.5 Foodgrain and Overall Crop Yields by Major States (1983-84)
(Yield of non-foodgrains is in food energy equivalents, FEES)

State	Irrigated Yield (Kg/Ha)		Unirrigated Yield (Kg/ha)		Yield Differential (Kg/ha)	
	Foodgrains	Total	Foodgrains	Total	Foodgrains	Total
Punjab	2999	3025	1359	1314	1640	1711
Haryana	2258	2328	583	606	1675	1722
Gujarat	2291	2364	930	926	1361	1438
Rajasthan	1519	1509	635	661	884	848
Bihar	1412	1429	838	890	574	539
Uttar Pradesh	1914	2292	983	977	931	1315
Orissa	1651	1755	964	961	687	794
West Bengal	1953	1918	1092	1078	861	840
Madhya Pradesh	1566	1637	945	943	621	694
Maharashtra	1285	2563	752	767	533	1796
Andhra Pradesh	2083	2257	684	796	1399	1461
Karnataka	2377	3058	803	808	1574	2250
Tamil Nadu	1938	2373	730	852	1208	1521
Kerala	1795	1795	1521	1521	274	274
Average*	1980	2208	864	877	1116	1331

* Note: Average also includes Assam, H.P. and J&K States.
Source: Dhawan (1988).

Table 1.6 Yield Impact of Irrigation from Selected Government Projects
(Yields expressed in Rice Equivalent Units)

Project Name	State	Irrigated Yield (kgs/hectare)	Unirrigated Yield (kgs/hectare)	Percent Increase
Bhakra Nangal	Punjab	2596	1167	122
Rajasthan Canal	Rajasthan/Punjab	1930	-	-
Jayakwadi	Maharashtra	2109	437	383
Nagarjunasagar	Andhra Pradesh	3077	1022	201
Tungabhadra	Karnataka	3353	1031	225
Gandak	Uttar Pradesh	2498	1053	137
Sarda Sahayak	Uttar Pradesh	1734	700	148
Tawa	Madhya Pradesh	1986	834	138
Mayurakshi	West Bengal	3638	1053	245
Mahanadi Delta	Orissa	1398	834	68

Source: Dhawan (1989)

1.13 Some indication of the impact that different types of irrigation have on yields can be gained from the analysis summarized in Table 1.7. An important conclusion is that land irrigated from private wells has notably higher productivity than from canals, which can also be readily observed in field visits. The principal reason for this is that farmers with wells have much better control over water than is possible through canal irrigation. In turn, tanks were found to have lower yields than canal irrigation probably reflecting the greater dependency of tanks on seasonal surface water supplies. Some care must nevertheless be taken in interpreting these results for the purpose of orienting investment decisions. Firstly, wells are frequently dependent on replenishment of groundwater by percolation from surface irrigation water supplies. This applies particularly in drier areas such as the northwest. Secondly, part of the yield from wells may reflect conjunctive use of both surface and groundwater supplies. Notwithstanding, well irrigation, as necessary in conjunction with surface irrigation, is clearly an attractive means to increase yields.

Table 1.7 Land Productivity Per Net Irrigated Hectare by Sources of Irrigation
(Ton/Ha in foodgrain energy equivalent units)

State	Wells (private)	Canal Irrigation	Tank Irrigation
Andhra Pradesh (1977-79)	5.7	3.4	2.0
	(1.46)	(1.31)	(1.24)
Tamil Nadu (1977-79)	6.5	2.6	2.3
	(1.61)	(1.30)	(1.12)
Punjab	5.5	3.2	-
Haryana	5.7	2.4	-
Madhya Pradesh (1977-78)	2.8	2.0	1.5
Karnataka (1976-77)	4.2	3.5	2.3

Figures in brackets indicate irrigation intensity.
Source: Dhawan (1988)

1.14 Very little information is available on yields per unit of water. This is recommended for future analysis and is likely to add refinements to the above perspectives. Yields under the warabandi system in northwest India would emerge even more favorably, while the very high yields found in some southern and eastern delta commands where water is relatively abundant, and in high water usage for such crops as sugar cane or in localization irrigation schemes, would be seen to be less impressive. Given the scarcity of water this perspective must be included in design of irrigation.

Stabilization of Output

1.15 Two recent studies have examined the role of irrigation in stabilization of farm output and its protective role during droughts. Dhawan (1988) and Rao et. al (1988) analyzed annual data from irrigated and unirrigated agriculture in 11 states for the period 1970-71 to 1983-84 and both studies concluded that instability is reduced under irrigated farming (Table 1.8; details by state in Annex Tables 1.2 and 1.3). The data by state illustrates that the stabilizing impact of irrigation is less evident in higher rainfall areas or where irrigation is itself substantially dependent on rainfall. In northwestern states with both snowmelt and high groundwater usage influencing reliability of irrigation, irrigated agriculture shows little annual variation. By contrast, in Bihar and Madhya Pradesh where uncertainties in irrigation water supply can be high, irrigated agriculture shows a (non-significant) slightly higher variability than rainfed agriculture.

Table 1.8 Stabilizing Impact of Irrigation on Productivity
(Coefficients of Variation in % on Trends between 1970-83, Aggregate Data from 11 States)

	Irrigated Lands	Rainfed Lands
Crop Area	1.9	2.9
Yield	4.3	9.3
Production	5.4	11.4

Source: Dhawan (1988)

1.16 These recent analyses do not support the much disputed earlier inferences on the impact of irrigation discussed by Hazell (1982) and Mehra (1983)[4] who felt, based on more limited data available then, that development of irrigation and associated inputs might be contributing to the instability of production that was notable in the 1970s compared to the 1960s. Some destabilizing impact might, however, be present at local levels where water supplies are uncertain yet conducive enough to farmers to take risks with higher yielding varieties and use of fertilizer. These practices would give good yields in favorable years, but are riskier than traditional practices in bad years. Situations like this may be common in Madhya Pradesh and Bihar. Nevertheless, in most states and at more aggregate levels the data that is now available points to a substantial stabilizing effect as a result of irrigation. Table 1.9 compares data from drought years in the 1970s. Output reductions on rainfed lands are much larger than shortfalls on irrigated lands (Annex Table 1.4).

[4] Instability in Indian Foodgrain Production, P. Hazell, IFPRI Research Report No. 30, 1982; and Instability in Indian Agriculture in the Context of the New Technologies, S. Mehra, IFPRI Research Report No. 25, 1981. Subsequent critiques (e.g. Dhawan) have commented that such findings suffered from biases inherent in the periods available for comparisons and narrower definition than in more recent studies of production.

Provisional assessment of data from the 1987-88 drought also points to a much lower susceptibility to drought of Indian agriculture.

Table 1.9 Impact of Drought Years on Output from Irrigated and Unirrigated Lands
(Percent Reduction from Trend Output)

Drought Year	Total Output		Foodgrains Output	
	Irrigated Lands	Rainfed Lands	Irrigated Lands	Rainfed Lands
1972-73	7	20	8	18
1974-75	7	13	10	14
1979-80	10	20	6	22

Source: Dhawan (1988). Annex Table 1.4 for state level data.

Cropping Patterns and Diversification

1.17 The principal influence of the expansion of irrigated agriculture on cropping patterns has been to encourage a very large expansion in the cultivation of wheat and a somewhat lower expansion in rice cultivation.[5] Table 1.10 illustrates the changes in cropping patterns that have occurred. From 1960-63 to 1980-83, 69% of additional gross irrigated area was utilized for foodgrains. The very rapid expansion in wheat cultivation took up 52% of the expansion in gross irrigated area, with the share of irrigated wheat in total gross irrigated area increasing from 15 to 31%. Expansion of irrigated rice - 16% of the expansion in gross irrigated area - was the other main development, though because of the much larger expansion in wheat, the share of rice in irrigated area fell from 45 to 32%. In most of the major rice growing states, rice is largely rainfed.

1.18 The predominance to date of wheat and rice expansion in India's irrigation development has been due to the development under India's "Green Revolution" of technology capable of achieving much higher yields from these crops. The combination of irrigation, suitable high yielding varieties and use of fertilizer has greatly increased yield prospects where irrigation is reliable and flood conditions are not prevalent. Additionally, Government's policy towards food self sufficiency has resulted in provision of assured markets and prices for foodgrains and concentration of research and other support service efforts on these crops. Returns from wheat and rice have become more profitable than coarse cereals (maize, sorghum, millet and ragi), while suitable technical packages for other crops have been much harder to find. Another factor has been that the frequent absence of control of irrigation water at farm level - for instance, under field-to-field water distribution systems in eastern India and a number of deltas where rice may be the only crop possible - has left farmers with little individual choice. Thus, in a number of states, wheat and rice have become major cash crops.

1.19 Some tendency towards diversification to other crops is nevertheless discernable from aggregate figures. About 18% of the expansion in gross irrigated area is represented by oilseeds, cotton and sugarcane with a combined share of additional irrigated area greater than that of rice

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5 The influence of HYVs technology on cropping pattern is also important. However, it is difficult to measure the extent of influence of each of the various inputs because of problems of multicollinearity. HYVs were largely confined to irrigated agriculture.

(16%). Irrigated oilseeds have expanded rapidly, now making up 9% of the additional irrigated area, but oilseeds still remain primarily a rainfed crop (86% of crop area under oilseeds). The irrigated area under sugarcane and cotton has also increased substantially. However, their share in gross irrigated area continues to be low (around 10%). The share of sugarcane would be much higher if irrigation was measured in terms of quantity of water. For instance, in the dry region of Maharashtra, sugarcane uses about 50 percent of available irrigation water though it covers only 10 per cent of gross cropped area (Rath & Mitra 1987). Finally, rapid growth has occurred in such diversification crops as fruits and vegetables.

Table 1.10 Changes in Crop Pattern in India 1960-63/1980-83

Crop/Crop Group	Total Irrigated/Cropped Area in '000 Hectares		Percent share in Cropped/Irrigated Area		Percent share in Additional cropped/ Irrigated Area
	1960-63	1980-83	1960-63	1980-83	
I. All Crops (Irrigated & Unirrigated)					
Rice	34839	39707	22.4	22.7	25.3
Wheat	13362	22663	8.6	13.0	48.3
Other Cereals	44661	41553	-	-	-
Pulses	24023	23044	15.5	13.2	-
Foodgrains	116885	126967	75.3	72.8	52.3
Oilseeds	13254	16889	8.5	9.7	18.9
Sugarcane	2371	3073	1.5	1.8	3.6
Cotton	7773	7917	5.0	4.5	0.7
II. Irrigated Crops*					
Rice	12946 (37)	16508 (44)	45.2	32.2	15.8
Wheat	4385 (33)	16015 (84)	15.3	31.3	51.6
Pulses	2015 (8)	1288 (6)	7.0	2.5	-
Foodgrains	22625 (19)	38117 (30)	79.0	74.5	68.7
Oilseeds	462 (4)	2449 (14)	1.6	4.8	8.8
Sugarcane	1622 (68)	2615 (85)	5.7	5.1	4.4
Cotton	1032 (13)	2217 (28)	3.6	4.3	5.2

* Figures in brackets indicate percent crop area irrigated.

Data Source: GOI; Area and Production of Principal Crops

1.20 Crop diversification under irrigation is illustrated more completely in Table 1.11. Starting from a small production base in 1960/61, growth has been appreciable except in the case of pulses. Overall, the irrigated area under diversification crops has doubled between 1960/61 and 1984/85

and share of irrigated area has risen slightly from 27 to 29%. Nevertheless, overall, irrigated agriculture is less diversified than rainfed agriculture as can be deduced from the data in Annex Table 1.5 where at the all India level, non cereals represented 41% of gross cultivated area. The degree of diversification varies considerably between states with a tendency for a larger presence of cereals in the wetter mountain and eastern states where water control under irrigation is also poor, and greater diversification in western and southern states. State level data for irrigated agriculture is not available, though individual statistics indicate a higher proportion than the all India average of non cereals under irrigation in Gujarat, Madhya Pradesh, Maharashtra and southern states.

Table 1.11 Development of Irrigated Diversification Crops (1960-61 to 1984-85)

Crop	Gross Irrigated Area in Million Hectares			
	1960/61	1970/71	1980/81	1984/85 (Provisional)
Oilseeds	0.4	1.1	2.3	3.5
Cotton	1.0	1.4	2.1	1.9
Sugarcane	1.7	1.9	2.3	2.5
Fruits & Vegetables	0.5	1.0	1.8	2.0
Condiments & Spices	0.4	0.7	0.8	0.9
Pulses	1.9	2.0	2.0	1.7
Other Diversification Crops	2.0	2.1	2.9	3.2
Total Diversification Crops	7.8	10.1	14.3	15.8
Total Cereals	20.2	28.1	35.6	38.2
Total Gross Irrigated Area	28.0	38.2	49.9	54.1

Source: Directorate of Economics and Statistics. Data has been rounded.

1.21 Greater agricultural diversification can be expected in the future. Demand for cereals is likely to rise by about 2.4% per annum to the year 2000, with slightly higher demand growth for wheat and lower demand growth for coarse cereals (1.4%). Much higher demand growth is expected to occur for non cereals: 3.1% for pulses; between 3.5 and 4% for fruits and vegetables, edible oils, sugar and animal proteins; and over 4% per annum for milk and the "other food" category (Radhakrishna and Ravi, 1990). Higher demand growth for fibers (cotton and silk) is also anticipated. Irrigated agriculture will increasingly need to respond to the development of demand patterns.[6] Better water control will be a key determinant in the ability of irrigated agriculture to diversify.

6 Though India's comparative advantage needs to be considered and current price distortions need adjustment (Country Economic Memorandum, World Bank 1991).

C. Employment and Incomes

Employment Impact

1.22 Various studies confirm the expected impact of irrigation on employment creation at farm level, but results differ widely depending on crops grown, the yield and cropping intensity, the degree to which irrigation influences the switch to more labor intensive crops, and other factors such as mechanization. Results from Daines and Pawar's work in Maharashtra (1987) in Table 1.12 are illustrative of the variability found. For most crops, the range of additional employment per hectare as a result of irrigated rather than unirrigated agriculture is between 50 to 100% more labor per hectare than under rainfed conditions. The lower impact in the case of wheat may be due to the labor saving impact of accompanying increases in mechanization. Annex Tables 1.6 and 1.7 show the results from surveys in Maharashtra, Rajasthan and Karnataka.[7] The results in Maharashtra (Annex Table 1.6) indicate an overall incremental labor usage of 75 mandays/ha under irrigation compared to typical labor inputs on millets and sorghum before irrigation of 50 days/Ha. The high average estimate for incremental labor usage is influenced by switches to very labor demanding crops such as sugarcane. A switch from coarse cereals to paddy or groundnuts would involve incremental labor of about 35 to 40 days per hectare. Roy found lower incremental labor usage under irrigation of about 30 mandays/ha in Rajasthan (Annex Table 1.6). Kamble's analysis of labor usage before and after well irrigation in Karnataka has much higher labor use figures for both rainfed and irrigated agriculture, with incremental labor of between 90 to 110 days per hectare (Annex Table 1.7). Perhaps of greatest interest is the finding in that study that while family labor increased, additional hired labor was substantial. Others have commented that irrigation, especially on smaller farms, primarily impacted on greater family labor input. A detailed analysis of labor use in Ferozepur district, Punjab, showed a 40% increase in labor input per hectare during the period from the mid-fifties to late sixties which was made up of switches in cropping pattern to more labor intensive crops and the output impact of irrigation (Mehra 1976). Another important finding was that the output impact of irrigation on labor was partly neutralized by rapid mechanization in the district. These various studies clearly indicate a strong employment impact from irrigation, though the variability of the results makes it difficult to provide a precise assessment of the average impact.[8]

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[7] Based on different studies by Kamble (1979), Patil (1980) and Roy (1983).

[8] Plan documents have also commented in the past on the employment generated during construction of irrigation schemes. In October 1988, a study of 40 projects indicated an average employment generated by one million rupees investment expenditure of 32 man years. Some 3.6 million manyears of jobs, over 70% unskilled labor, are estimated to have been created during the construction program of the Seventh Plan.

Table 1.12 Estimates of Employment Generated by Irrigated and Rainfed Crops in Maharashtra
(Person days/Ha)

Name of Crop	Rainfed Employment	Irrigated Employment	Additional Employment (Irrigated over Rainfed)
Fodder Crops	12-44	28-55	11-16
Rice	32-54	53-80	21-26
Jowar	22-50	37-64	14-15
Bajra	22-44	27-54	5-10
Wheat	22-33	27-39	5-6
Pulses	22-33	32-53	10-20
Oilseeds	22-33	32-43	10
Cotton	95-240	125-350	30-90
Groundnut	60-120	100-190	40-70
Spices	120-190	240-320	120-130

Source: Daines & Pawar (1987).

1.23 Another perspective can be gained from examination of agricultural employment elasticities (responsiveness of employment to changes in agricultural output). Based on cost of cultivation surveys for 1971-72 to 1983-84, an average agricultural employment elasticity of 0.59 has been estimated (World Bank, 1989). As a principal engine of past agricultural growth, irrigation can be assumed to have played a large role in the growth of employment resulting from agricultural growth.

Income Impact

1.24 The impact of irrigation on crop yields, cropping intensity and possibilities for substitution to higher value crops, translates to substantial differences in income between irrigated and unirrigated farming. Table 1.13, based on a survey in Gujarat (Patel and Patel, 1986), indicates that net income per hectare on irrigated farms was on average more than double the net incomes on rainfed farms.[9]

[9] Also of interest is that while net income per hectare is very similar across farm sizes in the rainfed sample, net income per hectare increases with larger farm size despite a tendency for cropping intensity to fall. Findings from other surveys indicate that this may not be typical. A possible explanation here is that increasing farm size was accompanied by an increase in technological sophistication and presence of higher return cash crops with larger farm sizes.

Table 1.13 Income Impact of Irrigation at Farm Level in Gujarat
(In Rupees per hectare)

Farm Size	Net Income		Difference in Net Income	Cropping Intensity	
	Irrigated	Unirrigated		Irrigated	Unirrigated
Marginal	1228	666	562	196	122
Small	1390	872	518	169	129
Medium	1783	733	1050	162	124
Large	1862	819	1043	150	120
All Farms	1695	799	896	159	126

Source: Patel & Patel, (1986)

1.25 Table 1.14 compares data from 3 unirrigated districts with 3 irrigated districts in Andhra Pradesh. Per capita monthly expenditure levels were used as a proxy for incomes. Per capita expenditures were on average 61% higher in the irrigated districts. A striking feature is that even for the two farm size categories below one hectare (classified as marginal farms) in the irrigated districts, per capita incomes about equalled or exceeded incomes from rainfed farms in the top size category (4 hectares and above). The impact of farm size on the benefits from irrigation is also apparent. For a marginal irrigated farm (below 1.0 ha), per capita expenditure was found to be on average 35% greater than marginal rainfed farms, while for farms over 4 hectares, per capita expenditures were 123% greater in the irrigated districts. Thus, while irrigation confers benefits in all farm size categories, the benefit is relatively greater for larger farmers.

Table 1.14 Average Monthly Per Capita Expenditure for Different Land Holding Groups in Six Rural Andhra Pradesh Districts (1983)
(In Rupees)

Land Holding Group (Hectares)	Unirrigated			Irrigated		
	Anantapur	Kurnool	Mahboob Nagar	East Godavari	West Godavari	Krishna
0.00 - 0.12	68.0	60.9	73.2	94.8	86.7	93.1
0.13 - 1.00	80.3	77.7	100.0	131.8	95.3	120.2
1.01 - 2.00	87.3	68.3	85.6	140.3	110.4	135.7
2.01 - 4.00	83.0	76.1	95.4	188.2	169.3	154.3
4.01 & above	101.1	83.2	100.4	283.6	132.6	219.6
All Cultivators	87.9	79.5	95.4	152.3	116.9	154.7

Source: Country Economic Memorandum, World Bank Report No 7616-IN, 1989 (based on National Sample Survey, 38th Round)

1.26 For farmers receiving irrigation, by far the most important influence on their crop production possibilities and income is the quality of the irrigation service provided. Different yield influences by type of irigation are shown in Table 1.7. Another illuminating example is provided

in Table 1.15 which compares returns per hectare from different locations in a Maharashtra surface irrigation scheme as well as returns from unirrigated farms (Brahmabhat, 1988). Farmers at the head of the command, and presumably with the best access to water, got twice the net income per hectare of rainfed farmers. By contrast, farmers at the tail of the command had very similar gross incomes, expenditures and net incomes per hectare as did rainfed farmers, a frequent situation at the tail of many commands where in practice the paucity, if at all, of water supply results effectively in little or no change to rainfed practices and returns for tail enders. A very interesting finding is that farmers in the middle reaches had higher gross returns (by 28%), marginally higher expenditures, and resultant higher net returns per hectare (by 48%) than farmers at the head of the command. This result is consistent with field observations that can be made in many commands in India of head end farmers frequently overwatering crops to the detriment of yields, while middle reach farmers, while considering themselves under water shortage, may in fact be much nearer to optimum crop water requirements than their head end counterparts. Better knowledge by farmers of crop water requirements would have significant productive and equity impact.

Table 1.15 Gross Income, Expenditure & Net Returns per Hectare of Cropped Area by Different Canal Zones in Maharashtra
(Rs/Ha)

	Gross Income	Expenditure	Net Income
Canal Irrigator			
Head	10461	5203	5258
Middle	13344	5559	7785
Tail	6518	3686	2832
Overall	10419	4886	5333
Non-Canal Irrigator	6042	3295	2747

Source: Brahmabhatt, 1988

D. Impact on Regional Development and Poverty

1.27 The findings above - a strongly positive impact on productivity, employment and incomes - have illustrated that development of irrigated agriculture, associated with the technological changes that have accompanied it (use of high yielding varieties, fertilizer) has had substantial impact on agricultural growth and poverty alleviation. However, impact has been very variable by region and between irrigation systems and has often been very inefficient. As discussed earlier, specific isolation of the impact of the irrigation variable is difficult because of the complex technological and cropping pattern changes that it induces. Irrigation is not only accompanied by technology changes at the farm level. At state and district levels, higher development of irrigation has frequently been accompanied by development of other infrastructure (roads, credit, marketing, electrification and schooling, Annex Table 1.8). Autocorrelation problems thus severely complicate quantitative assessments. Nevertheless, it can reasonably be affirmed that provision of effective irrigation fundamentally alters the agricultural environment permitting agricultural response along a more productive and intuitively more elastic production function. Much higher productivity is thus achievable. In turn, productivity improvement translates into income improvements per unit of land, influencing income levels and the incidence of poverty.

1.28 District level data shows a very strong association between the level of productivity (and by inference, incomes) and the extent of development of irrigation and other inputs. This is illustrated in Table 1.16 based on Bhalla and Tyagi's work. Districts with productivity levels above 1000 Rs/ha have a much higher percentage of land under irrigation than lower productivity districts. Similarly, usage of fertilizer, pumpsets and tractors is also high. Disparities between districts are very evident. Thus, in the 53 districts belonging to the two highest agricultural productivity groups, while their combined share of India's gross cropped area was only 19%, share of national gross irrigated area was 35% and share of fertilizer consumption 41%. At the other extreme, 144 districts accounting for 56% of India's gross cropped area accounted for only 35% of national output, 33% of irrigated area and 26% of fertilizer consumption.

Table 1.16 Distribution of Districts and Input Use by Productivity Levels (1980-83)

	Productivity Levels (Rs/Ha)*					All Levels	Above All India
	2000 & above	1500-2000	1000-1500	500-1000	0-500		
I. Input Levels							
No. of Districts	26	37	74	115	29	281	132
Gross Irrigated Area as % of Total cropped Area	65.11	95.18	76.15	38.83	20.98	29.57	46.16
Fertilizer Consumption (Kg/Ha)	87.94	131.27	91.96	36.76	10.85	34.07	58.55
Pumpsets (per '000 Ha)	44.31	116.60	68.99	40.36	21.50	28.25	41.06
Tractors (per '000 Ha)	5.34	5.25	3.52	1.60	1.26	1.57	2.68
II. Percent Share in Input Use							
Gross Cropped Area	8.33	10.56	24.93	44.96	11.22	100.00	41.94
Gross Irrigated Area	18.34	16.80	32.17	28.57	4.13	100.00	65.48
Output	18.19	17.58	29.23	31.52	3.49	100.00	63.16
Fertilizer	21.50	19.91	32.94	23.53	2.11	100.00	72.08
Pumpsets	13.07	21.38	29.43	31.10	5.03	100.00	60.96
Tractors	28.37	16.56	28.04	22.63	4.39	100.00	71.73

* All India Average Productivity based on 41 crops at constant prices during 1980-83: Rs. 1039 per hectare.
Source: "Patterns in Indian Agricultural Development - A District Level Study"; G.S. Bhalla & D.S. Tyagi (1989).

1.29 The strong association between agricultural incomes and levels of irrigation and inputs usage is also reflected in the incidence of poverty. Table 1.17, based on Rao's work, shows a marked reduction in the incidence of rural poverty in National Sample Survey regions where irrigation development exceeds 50% of cropped area.

Table 1.17 Percentage of Population Below the Poverty Line in Relation to the Percentage of Area Irrigated (1973)

Gross Irrigated Area as per cent of the gross cropped area in the triennium ending 1973	Number of National Sample Survey Regions	Percentage of population below the poverty line
Below 10 per cent	16	68.8
10-20 per cent	13	53.7
20-30 per cent	10	45.6
35-50 per cent	8	48.4
above 50 percent	7	26.5

Source: Rao et al (1988).

Impact on Regional Development

1.30 The very unequal distribution and growth of irrigation between districts in India has had its impact on the regional distribution of rural incomes and agricultural growth (Table 1.18). The region where benefits from irrigation are most obvious is the northwest, best exemplified at state level by Punjab statistics, but also including Haryana, western Uttar Pradesh, and northwestern corners of Rajasthan and Madhya Pradesh. In this region, irrigation covers more than half of net cropped area (82% in Punjab and 62% in Haryana) and an even higher proportion of gross cropped area. Furthermore, rapid development of irrigation occurred in the 1960s and 1970s (in Punjab, the percentage of net cropped area under irrigation increased from 53% to 82% between 1960-63 and 1980-83, a further 29% coverage in 20 years). The northwest was the center of India's "green revolution" involving the rapid uptake by farmers in the use of high yielding varieties of wheat and rice and fertilizer usage in conjunction with irrigation.[10] Other agricultural developments, including use of farm machinery, followed in the northwest. This development would not have been possible without irrigation. Punjab and Haryana have low rainfall, generally less than 600 mm per annum, making the land suitable under rainfed conditions only for such drought tolerant crops as sorghum and millet with a probable annual yield of less than 1 ton. Irrigated yields in Punjab now average 3 tons (rice and wheat). As a result of the transformation in agricultural productivity brought about by the green revolution, agricultural growth has been high in the northwest as discussed by Bhalla and Tyagi (1989) and illustrated in Table 1.19. Punjab has an agricultural productivity per hectare more than twice that for India as a whole and a 20 year growth rate in productivity of 4.5% per annum compared with the India average of 2%. Growth in agricultural productivity in Punjab is plateauing after its tremendous growth from the initial uptake of HYVs, fertilizers and expansion of tubewells. Productivity growth in Punjab was 5.5% per annum between 1962-65 and 1970-73 and subsequently slowed down to 3.7% per annum between 1970-73 and 1980-83.

10 Selected areas in southern and western states, based on HYVs, fertilizer use and improved irrigation , also underwent "the green revolution".

Table 1.18 State and Regionwise Levels and Growth of Value Productivity of Major Crops
(at constant prices)

State	Average Value Productivity per Ha (Rs.)			% Annual Productivity Growth Rate
	1962-65	1970-73	1980-83	(1962-65 to 1980-83)
Northwest Region				
Haryana	705	1053	1406	3.91
Himachal	728	912	988	1.71
Jammu & Kashmir	713	1086	1433	3.96
Punjab	1027	1645	2272	4.51
Uttar Pradesh	796	952	1269	2.63
Northwest Average	812	1077	1461	3.32
Eastern Region				
Assam	1038	1108	1154	0.59
Bihar	835	902	923	0.56
Orissa	1009	928	956	-0.30
West Bengal	1199	1319	1293	0.42
Eastern Average	992	1048	1060	0.37
Western & Central Region				
Gujarat	639	791	1046	2.78
Madhya Pradesh	579	626	683	0.92
Maharashtra	505	405	703	1.86
Rajasthan	355	481	542	2.38
Western & Central Average	517	555	713	1.81
Southern Region				
Andhra Pradesh	916	932	1367	2.25
Karnataka	598	794	924	2.45
Kerala	1485	1636	1734	0.86
Tamil Nadu	1274	1543	1648	1.44
Southern Average	907	1063	1295	2.00
ALL INDIA	743	863	1064	2.01

Sources: Bhalla & Tyagi (1989) for productivity and ISR Table 1.

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Table 1.19: Development of Irrigation and Agricultural Productivity by Major States

State	Agricultural Productivity		Irrigation Development		
	Rupees/ha in 1980-83	Annual Growth 1962-65 to 1980-83	Net Irrigated Area ('000) 1984-85	Net Sown Area Irrigated in % (80-83)	Increase Since 1960-63 (% in 1980-83 less % in 1960-63)
Northwest					
Haryana	1406	3.91	2,189	62	30
Punjab	2272	4.51	3,621	82	29
Uttar Pradesh	1269	2.63	9,879	54	25
East					
Bihar	923	0.56	2,795	36	12
Orissa	956	-0.30	1,466	20	4
West Bengal	1293	0.42	1,980	35	10
Western and Central					
Gujarat	1046	2.78	2,240	21	14
Madhya Pradesh	683	0.92	3,010	12	6
Maharashtra	703	1.86	1,964	11	5
Rajasthan	542	2.38	3,204	20	7
South					
Andhra Pradesh	1367	2.25	3,522	32	5
Karnataka	924	2.45	1,693	14	5
Tamil Nadu	1648	1.44	2,640	48	7
ALL INDIA	1064	2.01	41,779	28	9

1.31 By contrast, the states of eastern and central India (Bihar, Orissa, and Assam, east Uttar Pradesh and much of Madhya Pradesh) have fared much more poorly with growth of less than 1% per annum. This region is of particular concern for India's development. Inclusive of Madhya Pradesh and Uttar Pradesh, they represent 48% of net cultivated area and contain about 80% of India's rural poor. Raising the agricultural productivity in eastern and central India is thus of critical importance both in terms of raising India's overall agricultural growth and for addressing rural poverty. As discussed by a number of Government commissions and other reports[11], a complexity of constraints have applied in these states including high population pressure (resulting in very small farms with little financial capability to make investments or take risks) a high level of land fragmentation, tenurial practices in some sub-regions such as share cropping, and poor development of roads, commerce and Government services. Paradoxically, this region is far better endowed with rainfall and potential for irrigation development than any other region.

11 Agricultural Productivity in Eastern India, Report of the Committee on Eastern India, Reserve Bank of India, 1984; Report of Study Group on Agricultural Strategies for Eastern Region of India, Planning Commission, GOI, 1985; and India, Agricultural Technology Review, Asia Region, World Bank, 1989.

1.32 Irrigation is not only poorly developed in the eastern and central states (the share of net irrigated area in net cropped area is only 12% in Madhya Pradesh, 20% in Orissa, about 35% in Bihar and West Bengal, and irrigation is also less developed in eastern Uttar Pradesh) than in the northwest states, but its impact has also been much lower. This can be expected in wetter regions as productivity from rainfed agriculture should be higher. An important factor, however, has been the quality of surface irrigation and drainage in these states which has been unresponsive to agricultural needs. For the kharif rice and rabi wheat cycle prevalent in eastern Uttar Pradesh, Bihar and parts of Madhya Pradesh and West Bengal, the critical crop need is for early provision of water before the monsoon for rice nurseries and subsequent early transplanting of rice seedlings before the main rains. This ensures good tillering and resultant crop density as well as allowing application of fertilizer before monsoon flooding inhibits tillering and benefits from fertilizer. A good rice yield is possible where such early establishment is feasible. Earlier harvesting of rice then permits early establishment of wheat, important for using the cool winter months to ensure good growth. Farmers in the eastern and central region who have been able through tubewell irrigation to adjust their planting calendars have obtained excellent yields, nearly comparable to those in the northwest. Only a small proportion of farmers, however, have had this opportunity. Private tubewell development, while increasing in eastern Uttar Pradesh and Bihar, is less prevalent in the eastern region due to the investment and social constraints besetting marginal and fragmented farming in eastern and central India. Surface irrigation has mainly been designed as protective irrigation for supplemental watering during the kharif (monsoon season). Predominant reliance on run-of-the-river diversion schemes (with no or minimal storage and thus dependent upon advent of the monsoon), means that the start-up of irrigation is itself monsoon dependent. Further, management difficulties have meant that, even during the monsoon, irrigation is unreliable and poorly distributed between the head and tail ends of commands. Public tubewells could theoretically allow for more temporally optimal applications of water, but management difficulties have seldom enabled this to be achieved. Finally, the prevalence of monsoon waterlogging and, in large areas, of flooding, with little drainage infrastructure to reduce these problems, also reduces yield prospects. Thus, in the eastern and central region, irrigation and drainage development are both limited in extent and, where present, have usually been unable to have major productive impact.

1.33 Remedying this situation requires tackling of a number of technical, institutional, social and organizational constraints. With regard to irrigation and drainage, the two most important government actions would be to substantially improve water management in existing surface irrigation schemes and to install drainage to reduce the impact of monsoon waterlogging. In much of eastern India, lack of drainage is a larger problem than the deficiencies of the surface irrigation system. In the context of water management, maximum effort is needed to find ways to provide water for establishment of rice nurseries and subsequent early field growth and tillering of the rice crop before the major monsoon rains arrive. A third important emphasis is to foster through credit and other support programs, the development of private shallow tubewells.[12] Successful attainment of these objectives will require major management improvements in the institutions concerned. Agricultural extension, research, and input supply also need major emphasis. Land consolidation is also often an important need.

1.34 In the western and southern states, state level data indicate that average agricultural productivity (rainfed and irrigated agriculture combined) is similar to or below the agricultural productivity of Bihar and Orissa, the exceptions being Andhra Pradesh and Tamil Nadu and to a

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12 Refer to "Assisting Poor Rural Areas Through Groundwater Irrigation. Exploratory Proposals for East India, Bangladesh and Nepal" (Kahnert, 1989, World Bank, Asia Regional Series, Report No. IDP 44); and "Uttar Pradesh Groundwater Development, Issues and Options" (India Agriculture Operations Division, World Bank, 1991).

lesser extent Gujarat (Table 1.19).[13] Such state averages reflect the dominance of rainfed agriculture at state level. In Tamil Nadu and Andhra Pradesh, irrigated lands represent 48% and 32% respectively of net cultivated area. Elsewhere, the proportion of irrigated lands is very low (11 to 14% in Maharashtra and Karnataka and probably lower in central and southern Madhya Pradesh, 21% in Gujarat). Productivity growth has, however, been better in these states than in eastern and central India.

1.35 It has not been possible to make a breakdown of agricultural growth on a state basis as between irrigated and rainfed agriculture. Accordingly, an important element in the understanding of agricultural growth in peninsular India - performance of rainfed agriculture - is not present. However, based on data in selected districts (Tables 1.14 and 1.16), it can be inferred that growth of irrigated agriculture has played an important role. Thus, in Gujarat, a tripling of net irrigated area in 20 years may be substantially responsible for its high growth performance, while the still modest proportion of irrigated lands (21%), would explain why, in spite of higher growth, the average productivity per hectare still remains lower than in Tamil Nadu and Andhra Pradesh. In Tamil Nadu, which has the highest agricultural productivity and a much higher proportion of irrigated land (48%), growth in productivity has been low, as has been the rate of expansion of irrigated area.

1.36 In summary, the above discussion supports the observation that inequalities in the extent and quality of irrigation and drainage investments in India have influenced inequalities in the rates of agricultural development across regions. Such consequences have been partly inevitable reflecting regional water resource imbalances, but were accentuated by the uneven rates of past irrigation development initially concentrated in the northwest. A deliberate Government policy to enhance irrigation development where feasible in other regions has, however, had some impact. In peninsular India, the regional impact has been limited by the predominant presence of rainfed agriculture. Further, irrigation performance in southern and western India is very variable and, despite some high yielding commands, many commands suffer from performance problems. In eastern and central India, despite the expansion of irrigated area, performance of irrigation is typically very poor and much needed drainage infrastructure is absent. As a result, development of surface irrigation in eastern and central India has had very disappointing results.

Impact on Poverty and Secondary Effects

1.37 Poverty Impact: In its direct effect, the impact of irrigation on poverty is very similar to the conclusions emergent from the discussion of regional impact above. The presence of effective irrigation and drainage creates significantly greater productive potential with resultant (somewhat lower) impact on farm incomes and employment. Where irrigation is not or cannot be present, such impact is obviously not there. Such regional polarities may be partly mitigated by labor movements and regional differences in employment impact.[14] Poverty impact is also linked to the existing wealth structure of the community. Larger farmers benefit more, at least in absolute terms, than smaller farmers, and direct benefits only go to landholders, though landless households benefit from increased employment opportunities and lower food prices.

1.38 Secondary Effects: The indirect or secondary effects of agricultural growth are in large part

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[13] Agricultural statistics for Kerala reflect the prevalence of tree crops and large reliance on non-agricultural sources of income.

[14] Rao (1989) has found that interstate disparities in real wages of agricultural workers has declined in recent years. Thus, while real wages of agricultural workers in Punjab rose significantly in the early phase of the green revolution, they virtually stagnated after the mid 1970s due to an increase in mechanization and migration to Punjab of agricultural labor. At the same time, real wages of agricultural workers in Bihar started rising due in part to out-migration of labor to higher wage areas.

regionally concentrated as well, though they are significant in areas where irrigation is present and has effective production impact. Hazell and Haggblade (1990) estimated that a 100 rupee increase in agricultural income generates an average 66 rupees of rural non-farm income, 38 rupees in rural areas and 25 rupees in rural towns. The multiplier was found to be higher in more developed states because of higher consumption linkages and input intensity. Thus, while a 100 rupees increase in agricultural income will generate 106 rupees of non-farm income in Punjab and Haryana, the impact on non-farm incomes in Bihar and Madhya Pradesh was found to be only 41 rupees.

1.39 An exception to the largely regionally bounded nature of irrigation's impact has been its influence on food prices. Between 1970 and 1986, foodgrain prices in India fell by about 20% relative to the price index for all commodities in India (Annex 1.9). This has had very direct bearing on real incomes of the urban poor and landless rural households for whom food prices are a large component in consumption. Even when irrigation development and expansion was concentrated in certain regions of the country, it impacted positively on other regions through government's procurement and public distribution policies.[15] Labor movements to higher growth areas have also helped reduce inequalities. Nevertheless, for the large areas in India likely to remain without irrigation, addressment of poverty will need to rely on improving the productivity of rainfed agriculture.

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15 i.e., India's agriculture pricing policy of purchasing in surplus regions (mainly the northwest for wheat and states in the south for rice) and selling at fixed prices in urban and deficit rural areas, partly offsets the regional imbalance of concentrated agricultural development in irrigated areas.

Chapter II: Water Resources and Physical Potential for Irrigation and Drainage Development

A. Introduction

2.1 Government estimates of ultimate irrigation potential[1] in India are based on figures developed by CWC for each State and Union Territory in 1981. Under this assessment, the ultimate irrigation potential was estimated to be 113.5 million hectares. This is about 34% of total land area, and 42.5% of the arable land. Of the estimated 113.5 million hectares of ultimate irrigation potential, 58.5 million hectares (52%) would be under major and medium schemes and the balance (55 M ha) under minor schemes, 40 million hectares served by groundwater and 15 million hectares by surface water[2]. The above estimates do not include additional waters which could be mobilized for irrigation and other uses by major inter-basin transfers of water which CWC (1980) estimated could create an additional 25 million hectares of irrigation potential[3]. A state-wise breakdown of CWC's 1981 estimate of ultimate potential is in Annex II (Table 8).

2.2 The Working Group on Irrigation for preparation of the Seventh Plan developed estimates of the irrigation potential created by 1984/85. This assessment indicated that the total potential created was then about 68 million hectares of which about 45% (30.5 M ha) was on major and medium schemes and about 55% (37.5 M ha) on minor schemes. The total potential created in 1984/85 was about 60% of the ultimate potential assessed in 1981, with major and medium schemes representing about 52% of their ultimate potential and minor schemes being about 68% of ultimate potential. Details by states of irrigation potential created in 1985 are given in Annex II, Table 9.

2.3 Utilization of irrigation potential created by 1985 was reported to be 89% of the potential created. Utilization of major and medium schemes averaged 83% of potential created, while minor schemes averaged 94% (Annex II, Table 9). Shortfalls in utilization are due to several factors. There are ambiguities in the definition of "potential created" and "utilized". The estimate of potential created is based on assumptions of design cropping patterns which may not be realized or chosen by the cultivators. Moreover, many schemes have been designed on the basis of optimistic assumptions of irrigation system efficiencies, and water supplies at field level have proved to be less than anticipated (Volume I, para 4.28). Finally, creation of irrigation potential is frequently assumed when headworks and major canals have been constructed and does not take account of whether the minors and microdistribution network have also been completed, a widespread

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[1] The Indian definition of irrigation potential is the gross area which theoretically could be irrigated in a year on a scheme on the basis of the assumed design cropping pattern and a rainfall probability of 75%. Government estimates of irrigation potential discussed in this chapter must be treated with caution due to difficulties inherent in such estimations and several methodological issues which will be reviewed. Also, most of the estimates are based on assumed extensive irrigation systems with low irrigation intensities which are not always feasible.

[2] Major schemes are >10,000 ha, medium schemes are 2,000 to 10,000 ha and minor schemes are < 2,000 ha.

[3] In May 1990, the Government revised its estimates of ultimate potential to take account of potential which could be created by major basin transfers and additional potential for groundwater development. This increased the estimate of ultimate potential by about 40% to 158 million hectares (details of the revised estimates were not available for the sector review). However, harnessing of this additional potential would be difficult and technical evaluation remains to be done (para 2.30). Discussion of irrigation development potential in the medium term will thus be confined to assessment without taking account of such basin transfer possibilities.

problem with many projects remaining to be completed. The all-India situation in 1985 is summarized in Table 2.1.

Table 2.1 Government Estimates of Status of Indian Irrigation Development in 1985

	Major and Medium Schemes	Minor Schemes	Total
	---------- M ha ----------		
Ultimate Potential (1981)	58.5	55.0	113.5
Potential Created (1985)	30.5	37.4	67.9
Potential Utilized (1985)	25.3	35.2	60.5
Balance (Ultimate-created)	28.0	17.6	45.6
Land/Land Use Comparators			
Total Land Area	N.A.	N.A.	329
Total Arable Land (1985-86) (Rainfed & Irrigated)	N.A.	N.A.	266
Gross Cropped Area (1985-86) (Rainfed & Irrigated)	N.A.	N.A.	177.3

Note: A possible extra 25 M ha from basin transfers (para 2.1) are not included in ultimate potential.

2.4 The above estimates indicate that there is substantial scope for continued expansion or intensification of irrigation in India as a whole, though there is considerable diversity in the regional distribution of the remaining potential (Tables 2.3 to 2.5 and Annex II, Table 9). However, capturing additional surface water for irrigation is dependent almost entirely on creation of additional storage[4]. The environmental and increasing resettlement problems involved in creation of new large reservoirs are well known. Moreover, the actual availability of groundwater to support expansion of irrigation is likely to be over-stated.[5] Furthermore, it is evident that any assessment of availability of water for irrigation must take account of the competing needs of water

[4] The following Government commentary is instructive in this regard.
"The dams constructed so far have a live storage of 14.3 million ha. m. The dams under construction have live storage of about 8 million ha. m. and the projects contemplated in future have also a live storage of about 8 million ha. m. Thus the total storage capacity likely to be created by major dams in India is about 30 million ha. m., which is about 40% of the (estimated) utilizable surface water resources and only about 16% of the available annual surface water resources. The total storage capacity of the thousands of tanks constructed aggregates only 3 million ha. m. or only 10% of the storage capacity through major dams." (R. B.Shah, CWC, 1989)

[5] *"Groundwater is not a distinct entity but is a part of the same quantum of water forming a part of a hydrological cycle. There is a two-way flow between surface and groundwater. In fact, in most of the rivers, the low flows are contributed by the groundwater. The groundwater can therefore supplement and augment the use of surface water but it cannot replace major dams. In fact, an erroneous feeling of unlimited availability of groundwater resulted in over exploitation in a number of States resulting in permanent damage. (Shah, CWC, 1989)*

supplies for community usage, industry and power generation, and also the needs for water to be left in the rivers for such uses as flushing, navigation and to maintain fisheries.

2.5 An exercise to better assess India's irrigation development potential was undertaken jointly with Government as part of this Review. This entailed an analysis, by each of India's major river basins or composite basins (apart from Brahmaputra and Barak), of surface water and groundwater resources and irrigation development, and an assessment of future irrigation development potentials and priorities (Barber, Patel et. al 1990)[6]. Summarized information on each river basin is given in Annex II, Table 3 and further discussion, based on the above paper, of development potential by States, and a discussion of demands for other uses of water are contained in the text of Annex II.

2.6 It should be emphasized that a precise quantitative statement by river basins, and subsequently by states, of future development potential is not feasible from the above evaluation exercises. This would require a much more detailed study, essentially of the kind undertaken to provide a detailed river basin plan. The need for river basin planning in India is indeed one of the obvious recommendation areas emerging from the present analysis (Section F). Hence, while in Section E of this chapter, Tables 2.3 to 2.5, based on unrevised Government estimates are used to illustrate an indicative picture of the regional distribution of irrigation potential, considerable caution is needed when using these tables. A number of important points have nevertheless emerged and are discussed below. In section B, a commentary is made on water resource availability, including a discussion of areas of uncertainty in estimating water development potential. Section C discusses competing uses for water and their implications for irrigation development. Section D highlights the main irrigation and drainage development opportunities in India, while section E discusses prospects from a regional perspective. Finally, Section F recommends a greatly stepped up planning process for water development in India, entailing a holistic approach based on river basin plans.

B. Water Resources and Irrigation Development Potential

2.7 Rainfall is very unevenly distributed in India, both spatially and temporally. Mean annual rainfall ranges from less than 100 mm in parts of the Rajasthan desert to more than 4,000 mm locally in the Western Ghats and in the extreme northeast of the country. The incidence of rainfall is also very seasonal, occurring mainly during the southwest monsoon in most of the country, except the extreme south, which also receives the northeast monsoon, and the western part of the Himalayas which receives significant winter precipitation. As shown in Table 1 of Annex II, most areas of the country receive 70-95% of mean annual rainfall during the June to September period. Moreover, extended dry spells can occur during the monsoon period. Without irrigation, the main determinants of crop production possibilities are rainfall levels and their seasonality and predictability. In most parts of the country, irrigation is essential for dry season cropping, and supplemental irrigation is necessary during the wet season to ensure reliable crop yields, especially with high yielding varieties and for many diversification crops. In the arid parts of west and northwest India, irrigation is necessary for cropping in all seasons.

2.8 Surface water availability in India is much less favorable than frequently assumed. It is estimated by CWC (1988), that the average annual natural runoff available to India (excluding the

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6 "Assessment of India's Water Resources and Irrigation Development Potential", Irrigation Sector Review Background Paper. Prepared by W. Barber and C. C. Patel in association with D. K. Dutt, J. I. Gianchandani, V. V. Byrappa (consultants) and Government representatives from MOWR, CWC and CGWB.

islands) is about 1,880 BCM[7]. This converts to a per capita average runoff of about 2,500 m^3/yr as compared to 17,500 m^3/yr in the USSR, 6,500 m^3/yr in Japan and 6,200 m^3/yr in the USA. In addition, the amounts of unit area runoff from the various basins of India vary widely, reflecting mainly the spatial distribution of annual rainfall. Moreover, most of the rivers of the country carry about 80% of their flow during the monsoon months of June-September and generally in excess of 90% during the period June-November. Thus, there is a very marked low flow season in December-May, and the rivers draining basins located in the Central Highlands and Plateau regions, which lack snow melt runoff, typically have extremely low flows at the end of the dry season. The problem of the very wide intra-annual variation of natural flow is compounded by the wide inter-annual variation of runoff.[8]

2.9 This situation has important implications on the need and potential for storage reservoirs. With such natural runoff regimes, capturing a large proportion of the average runoff for beneficial use would demand the creation of a very large volume of storage reservoirs in all the basins of the country. Unfortunately, as noted in Government comments under para 2.4, the total live storage available (including tanks) may only be about 334 BCM or about 17.5% of the mean annual natural runoff from the country. The storages created or under construction, including tanks, total about 253 BCM or about 13.5% of the mean annual natural runoff. The live storages created, under construction and under consideration (including tanks) total about 286.5 BCM, which represents only about 22% of the annual average natural runoff of 1,290 BCM in India.[9] There is thus both an important need to create further reservoir storage if India's water resources and their seasonally concentrated nature are to be used more fully, and eventual limits, even under such a program, concerning how much runoff can be captured. An additional emphasis should be to create better conditions for retention of monsoon rains in the soils as groundwater storage. This requires improved vegetative cover and such agricultural practices as vegetative (e.g., vetiver grass) bunding and contour cultivation.

2.10 CWC (1989) estimates the utilizable surface water flow by river diversion structures as 656 BCM/yr. The estimate appears to discount water left on the rivers for such uses as navigation and flushing. This estimate of utilizable flow as surface water represents about 51% of the estimated mean annual natural runoff from that area of India. About 250 BCM/yr or 38% of the above estimated utilizable flows is in the Ganga basin, but storage appears to be lacking in the basin to mobilize such flows beneficially.[10] This situation is repeated in most of the other river basins of

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[7] Billion cubic meters ($1x10^9$ M^3). The term BCM is the more commonly used nomenclature in India.

[8] For example, the 1948-1979 data series which provides a mean annual runoff from the Narmada basin of about 45 BCM, shows an extreme annual range of about 21-76 BCM.

[9] Figures here and in paras 2.10 and 2.11 exclude the Brahmaputra and Barak Basins.

[10] Present diversion for irrigation in the Indian part of the Ganga basin averages about 2,000 m^3/sec or about 63 BCM/yr, representing a present use by irrigation, the major user, of only 25% of the CWC estimate of utilizable flow in the basin, or about 12.5% of the mean annual natural runoff from the basin. India has created total live storage of 34 BCM through 45 major and 159 medium reservoirs in the Ganga basin, has projects under construction which will create 15.1 BCM of live storage, and has identified additional potential for creation of about 27.3 BCM of live storage. Thus the ultimate potential for live storage in the Indian part of the basin may be 76.4 BCM or about 30% of the CWC estimate of utilizable flow in the basin. Reservoirs which could be constructed in Nepal could double the live storage on the basin, but even with this storage in place, it is unlikely that utilization would reach

India.

2.11 Groundwater resources must also be considered. It should be noted that the natural runoff estimate provided by CWC is inclusive of groundwater outflow to the surface water drainage systems. This is important because the methodology used by the CGWB for evaluating groundwater resources does not specifically take account of the impact that developing the assessed groundwater resource would have on surface water flows, particularly in the dry season when effluent groundwater forms the major component of river flows which do not collect snow melt. The most recent estimate of replenishable groundwater resource in India, excluding the northeastern states, is 420 BCM/yr of which 357 BCM/yr are regarded as utilizable for irrigation after making a provision of 15% for community water supply and industrial uses (Annex II, Table 10). The present net draft for irrigation (after allowing for return flows) is estimated to total only about 106 BCM/yr or 30% of the estimated total utilizable for irrigation. Thus, the CGWB estimates indicate a balance of groundwater for development for irrigation of about 251 BCM/yr (excluding northeastern states). Accepting the caveat regarding double accounting of surface water and groundwater, and thus the probability that the total water resources (surface water and groundwater) are less than assessed, it is nevertheless evident that there is large scope for additional irrigation development in India based on groundwater. However, the remaining resource is not evenly distributed between States (Table 2.5 and Annex II, Table 10), and within large states such as Uttar Pradesh, the distribution between districts of the remaining resource varies markedly.

2.12 To summarize the situation with regard to future water resource development for irrigation:

(a) further large scale development of surface water for irrigation, once the currently ongoing projects are completed, will depend mainly on creation of storage;

(b) the potential for creation of additional storage in most basins is limited, and if the ultimate foreseen storage potential is achieved, the live storage will then represent only about 17.5% of the mean annual natural runoff from the country;

(c) taking account of (b), the estimates of utilizable flow developed by CWC appear optimistic; and

(d) though there is some double counting of surface water and groundwater, and the total water balances will be less than implied by the figures, there is considerable scope for additional groundwater development in many states, particularly in the eastern part of the country.

50% of the mean annual natural runoff, given the rainfall regime and the geometry of the basin.

C. Competing Uses of Water

2.13 Although irrigation is by far the greatest user and consumer of water in India, and this situation will continue into the foreseeable future, provision of domestic water supplies for urban and rural populations and assuring water supplies for livestock are given first priority under the National Water Policy (MOWR, 1987). This document also recognizes the water needs of hydropower, thermal power, industry and navigation. The need to maintain minimum flows on rivers for flushing pollutants, dilution of waste water and other environmental reasons such as the requirements of regenerative capacity of the economic system must also be recognized.

2.14 Irrigation. In an assessment of the water resources of India, CWC (1988) remarks that about 85% of present water use is for agriculture. CWC estimated that, in 1985, irrigation water use was about 470 BCM of which about 320 BCM from surface water and 150 BCM from groundwater. The document forecasts a water demand for irrigation use of 770 BCM in 2025 with 520 BCM from surface water and 260 BCM from groundwater.[11]

2.15 Community Water Supply. CWC (1988) reports that the estimated annual water requirement for domestic use and livestock watering was 16.7 BCM in 1985 and is forecast to reach 28.7 BCM by the year 2000 and 40 BCM by 2025. While the total water requirement for community use is not high in terms of India's total water resources, localized areas of high demand can create supply problems. Such problems are already presented by the urban conurbations of Delhi, Madras and Bombay and some other large cities, particularly in peninsular India. Provision of rural water supplies presents problems on a more regional scale in the drought prone areas of India. Whole regions may become very water short for extended periods, as was the case in large areas of Gujarat and Rajasthan during the prolonged rainfall short and drought years of 1984-87.

2.16 Industry and Thermal Power Uses. CWC (1988) approximately estimates that total industrial water use may have reached 17 BCM in 1989/90 and, due to the foreseen urbanization of population with associated industrial development, the water requirements for industry may reach 120 BCM in 2025. Light industries located in urban areas often take water from municipal supply, while many heavy industrial developments have developed captive water supplies. Some conflicts between heavy industry and irrigation are already developing, for example, in the Bihar part of the Subernarekha basin. The Central Electricity Authority (CEA) estimated the total water consumption at thermal power plants in India in 1987 as 2.7 BCM (reported in CWC, 1988).

2.17 Hydropower. The total installed capacity of hydropower plants in India is now about 15,600 MW. CEA (1989) estimates that there is potential for installation of 140,000 MW of installed capacity. Of this total, about 75% would be on Himalayan rivers and 40% of the total would be run-of-the-river schemes and the balance associated with reservoir storage. While the actual consumptive water use of hydropower facilities is very small, optimum facility operation requirements for power releases will often be in conflict with water release demands for irrigation and flood control.

2.18 River Flushing and Navigation. While the importance of river transport is recognized in India, and some rivers have been declared national waterways, the amounts of water required for such use on the rivers remain unquantified. The need to maintain minimum flows on rivers for flushing pollutants and silt, and for fisheries and other environmental reasons is self evident, but these demands are also mainly unquantified. The great Farakka barrage was built on the Ganga to ensure dry season flows on the Bhagirathi to prevent silting of Calcutta port. The discharges now

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[11] It should be noted that the demand is estimated at the primary diversion point, and a large proportion of the diverted water (50% or more) will be recycled back to the surface water or groundwater systems.

reaching Farakka in the low flow season (January-May) are often insufficient to allow the design capacity diversion while leaving an acceptable flow on the river for Bangladesh.

2.19 The volumes of future (year 2025) usage of water by the major sectors of the Indian economy, together with rough estimates of water consumed and return flows are summarized in Table 2.2. As noted previously (paras 2.15 and 2.16), consumption for community and industrial water supplies forms a very small part of India's water budget, but supplies must be very secure. Further, location specific high demands in competition with irrigation are present around urban centers and in some arid regions.

2.20 In conclusion, in aggregate terms, despite anticipated rapid expansion of water use for community and industrial needs and water needs for power, irrigation can remain the main user of water for many years to come. However, this situation does not necessarily apply in particular river basins or localities of river basins. Particularly near major metropolises and in dry regions, competing uses will need to take precedence and will limit the water available for agriculture. This situation has already arisen in a number of localities. An increasingly essential need is to plan and implement water resource development in the global context of its multiple uses. This will require closer collaboration between the MOWR (and its affiliate entities, the CWC and CGWB) and other concerned ministries at the center (e.g. functional bodies concerned with industry, health, water supply, power, navigation, etc.), between similar functional entities at state level, and between states sharing the same water resource in a river basin. Increased efforts on data collection and monitoring demand projections and water resource planning are recommended, with particular emphasis on river basin planning (Section F).

Table 2.2 Present Demand and Year 2025 Demand and Consumption of Water by Various Sectors in India

Sector	Present gross demand (BCM/yr)	Forecast Demand: Forecast gross demand (BCM/yr)	% of Total demand	Return Flow: %	Return Flow: Volume (BCM/yr)	Net demand (BCM/yr)	% of Total net demand
Irrigation	(570)	770	83	50	385	385	91
Community	(25)	40	4	70	28	12	3
Industry & Power	(17)	120	13	80	96	24	6
Totals	(612)	930	100		509	421	100

D. Irrigation and Drainage Development Prospects

2.21 India as a whole has considerable potential for further irrigation development in the medium term. However, the options and scope for irrigation development vary widely between states and regions. In the case of surface water, most of the easier and often most cost effective options have been taken up. New surface irrigation schemes must contend with increasingly marginal conditions in terms of physical setting and, in many cases, of economic returns. Increasing surface water supplies above what has to date been captured is dependent mainly on creation of additional storage, but most of the easier to create reservoir sites in India have been developed. The remainder usually present difficult inter-State agreement problems and/or large environmental and resettlement constraints.

2.22 Large investment in surface irrigation will need to continue over the next two decades for the completion of the very large inventory of surface water schemes which are under construction in many states. There is also considerable scope for additional groundwater development in a number of states. Investments for improving the performance of existing surface irrigation schemes should be a major priority and will have larger and quicker impact, and at lower cost, in the short and medium term than completion of ongoing projects. While investments in drainage have been lacking in most states (Punjab was an exception in the 1950s), development of drainage systems for surface water irrigated areas should assume much greater importance in the future, and may be associated with flood control developments in some situations. The following enlarges on the main areas of future scope for irrigation development.

Improvements to Existing Surface Water Irrigation Systems

2.23 A number of States have made investments in improvements to existing surface water systems to make better use of the available water supply. Notably, Punjab, Haryana and Gujarat, recognizing that their surface water resources are very limited, have invested heavily in canal and water course lining programs, and several modernization projects in the Plateau region have included similar system improvement components[12]. This type of modernization investment together with improvements to water regulation structures and communication systems should form an important part of the irrigation development program in states with very restricted additional water supplies.

2.24 However, state budget constraints often dictate that intensive modernization of irrigation systems must proceed relatively slowly, especially when compared to the large area requiring system improvements. Moreover, large scale lining investments may not be economically justified in many irrigation systems, particularly when considered at the basin level where water use efficiencies can be very high. An upstream system's loss is a downstream system's gain, and infiltration losses can be recovered as groundwater. The concepts developed under the Bank assisted National Water Management Project (Cr. 1770) are more appropriate for rapid application over large areas (Volume I, para 4.23). The concept concentrates on identifying the correct management decisions for proper operation of a system, with hardware inputs restricted to those essential for the operation to be effective. Such improvements involve relatively low investments. The concept could apply to large areas under surface water irrigation in most states of the Ganga basin, as well as to peninsular India where the project commenced. Improved water management (better provision to farmers of water as concerns reliability, timeliness and spatial distribution) will

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12 Canal and water course lining was a design concept for Karnataka's Upper Krishna Project, and is included in the designs for new systems based on Narmada waters in Gujarat and Madhya Pradesh.

have major impact on the productivity of agriculture in surface irrigation commands. Accordingly, a sustained drive to build up the coverage of the national water management program should be a top priority in India's irrigation and drainage development strategy (Volume I, Chapter IV).

Completion of Ongoing Projects

2.25 CWC (1989) records that 151 major projects which are under construction in the 14 major river basins of India will have irrigation potential totalling about 21.6 million hectares when they are completed. About 90% of the potential in incomplete projects is concentrated in five basins, with 14% in the Indus, 36% in the Ganga, 12% in the Godavari, 17% in the Krishna and 11% in the Narmada basins. The major parts of the incomplete works are located in Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar, West Bengal, Gujarat, Maharashtra, Andhra Pradesh and Karnataka. The CWC report does not indicate the degree of incompleteness of the 151 major projects, but it is clear that completion of ongoing works will need to have a priority place in India's public investment portfolio for irrigation over at least the next ten years. This evident priority must take full precedence over the situation that has caused the backlog of started but still unproductive investments to arise. That is, the tendency of state governments to commence new projects rather than concentrate on the productivity and sustainability of existing irrigation and drainage infrastructure and timely completion of ongoing investments.

Groundwater

2.26 CGWB's most recent estimate of the replenishable groundwater resources of India, exclusive of the Brahmaputra and Barak basins, is about 420 BCM/yr. After providing a reserve of about 15% for community water supplies and industry, the groundwater available for irrigation is estimated to be about 357 BCM/yr. The present net draft (after allowing for return flows) is estimated to total only about 106 BCM or about 30% of the estimated resource available for irrigation (Table 2.5 and Annex 1, Table 10). Despite the reservations regarding double counting of surface water and groundwater (para 4.11), there can be no doubt that large quantities of groundwater remain to be developed in many of the river basins and states of India. Given the high productivity and economic viability of (private) groundwater development discussed in Chapters I and III, continued development of private groundwater irrigation should be a major priority. Shallow tubewell facilities with capital costs of Rs. 7,000 and serving about 4 ha will generally be preferred in alluvial aquifer areas. However, large areas of India are underlain by hard rock aquifers which can be exploited for irrigation only by large diameter dug wells equipped with pumpsets. Such facilities have capital costs in the range of Rs. 35,000-45,000 and serve about 2.0 ha. The energy demands of pumping are high, and as most farmers will use electrical power (which is heavily subsidized), if it is available, the demands on electricity for agricultural pumping are critical in many states with limited power development. The budgetary burden of subsidies is also serious (Volume I, para 3.4).

2.27 A sound government program to foster rational development of private groundwater irrigation will have major impact on agricultural productivity and rural welfare, especially in eastern and central India where many districts still have large additional groundwater exploitation potential. In northwest India, the explosive growth of groundwater irrigation in the past 30 years has been a principal factor in the green revolution and similar impact is now spreading eastwards (for instance, in Uttar Pradesh). However, important changes of policy and improvements in resource planning are required. Irrigation subsidies must be removed if this is to be affordable and charging must be metered rather than at fixed rates which encourage wastage of electricity, overexploitation of water and put strain on rural electricity supply (Volume I, para 3.18). Investment in power generation and distribution is also required. Monitoring of groundwater levels and trends must also be stepped up and used in decisions regarding credit provision and other well and pumpset investment subsidies. Finally, investment in deep publicly managed tubewells should be halted in

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favor of private investment in shallow tubewells or, where necessary and without danger of overexploitation, in private smaller deep tubewells.[13]

Drainage

2.28 The agro-climatic conditions in much of India often require drainage in addition to irrigation for high productivity agriculture. Investments in drainage have now become opportune in view of the rising productivity potential of agriculture. The major thrust of the land drainage development in most of the country will be on removal of rainfall and runoff surplus through improved surface drainage systems. Conditions which would warrant such improvement may be found in most states in areas where lands are naturally imperfectly drained or man-imposed changes have caused drainage congestion. Lands provided with surface water irrigation facilities would normally have the highest priority for drainage improvements. In the range of 5-10 million hectares of land in India could economically justify provision of field and tertiary drainage. Such a program could be implemented over 20-25 years with costs in the range of Rs 1500-3000/ha or US$ 90-170 in 1990 prices (Smedema, 1990)[14]. As the Indo-Gangetic plain has the greatest concentration of surface water irrigation in India, the requirements for drainage works will also be concentrated in, but not exclusive to, the Ganga basin states. A number of delta irrigation schemes in southern and eastern India also require drainage investments.[15]

2.29 Groundwater drainage and, in some places, soil reclamation measures are required for the sustainability of surface water irrigated agriculture in areas underlain by saline groundwater in parts of Punjab, Haryana, northern Rajasthan and extreme western Uttar Pradesh. Amelioration of waterlogging is required immediately in parts of these states. Irrigation-induced water logging and secondary soil salinization in this situation can only be solved satisfactorily by artificially increasing the groundwater drainage capacity to restore the water and salt balances in the affected area. Installation of pipe drainage systems appears to be the most satisfactory solution. Surface water drainage systems are also generally required to relieve drainage congestion which has been exacerbated by high water tables reducing the runoff attenuation effects of infiltration. One of the major difficulties to solving the water logging problems in northwest India is disposal of the saline effluent. The total area that will eventually require groundwater drainage is estimated in the range of 250,000-500,000 ha (Smedema, 1990). The cost of drainage treatment for eliminating waterlogging and secondary soil salinization by pipe drainage is estimated at Rs. 20,000-25,000/ha ($1120 - 1400 per ha) exclusive of additional costs for disposal of the drainage effluent.

Storage Reservoirs

2.30 According to CWC (1988), India has the potential to create 82 BCM of live storage in new reservoirs in addition to the 143 BCM of live storage created and 73 BCM under construction. It is noteworthy that 56% of the additional storage that could be created is located in the Brahmaputra-Barak basin in the northeast where its main function would be for power generation. Nevertheless, creation of additional storage is essential for further growth of surface water irrigation, either through development of the waters within the basins of origin or for

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[13] A full analytical discussion of the issues and opportunities involved, applicable in many respects to other states, is contained in "Uttar Pradesh Groundwater Development, Issues and Options", Agriculture Operations Division, India Department, World Bank, February 27, 1991.

[14] Land Drainage and Reclamation, L.K. Smedema, 1990 (Irrigation Sector Review Background Paper).

[15] For instance, investment towards drainage has been included in the Andhra Pradesh Cyclone Relief Project (Cr. 2179/Ln. 3065).

implementation of conceptual plans for large scale basin transfers. Considering the situation regionally:

(a) there is little scope for increasing storage in the Indus basin in Punjab, Haryana and Rajasthan once the Thein dam on the Ravi river is completed (development in the Indus basin in Jammu and Kashmir and Himachal Pradesh is limited by the Indus Basin Treaty between India and Pakistan);

(b) there is scope for creating additional live storage totalling at least 6.5 BCM on the Ganga basin in India. Agreement could also be reached with Nepal for creation of storages on the Ganga tributaries for the mutual benefits of the basin's riparians. Such developments could benefit all the Indian States of the basin to varying degrees, though a basin transfer would be required to deliver water to Rajasthan;

(c) the Subarnarekha, Brahmani-Baitarani, Mahanadi and Godavari basins draining to the east coast have storage potentials under consideration totalling about 24 BCM which should be given high priority for their irrigation, flood control and power benefits to West Bengal, Orissa, Madhya Pradesh and Andhra Pradesh. In the cases of the Mahanadi and Godavari basins, the storage is crucial to plans for water transfers into the water-short basins of southern India;

(d) there is little scope for creation of additional storage in the eastward draining basin to the south of the Godavari; the Krishna, Pennar, Madras Composite, Cauvery and South Tamil Nadu composite basins. The CWC (1988) identifies live storages totalling only about 1.8 BCM as under consideration in this entire area which includes large areas in Maharashtra, Andhra Pradesh, Karnataka and most of Tamil Nadu; and

(e) the major river systems draining to the west coast (Tapi, Narmada, Mahi and Sabarmati) and the Saurashtra and Kutch areas offer only limited potential for additional storage after the completion of ongoing schemes (the largest of which are on the Narmada river in Madhya Pradesh and Gujarat).

2.31 The construction of additional storage is a clear medium and long term need for irrigation development. Without additional storage there will be little scope in the medium and longer term for expansion of irrigated area and catering to municipal and industrial needs. Storage based irrigation also provides the flexibility of using the water when needed at critical times during the kharif season (e.g., early planting, drought periods) and as possible in other seasons, greatly augmenting productive impact capability. However, the timing of investment in additional storage must be carefully considered. In most regions, far more urgent priorities are present related to getting existing irrigation systems to work well and be properly maintained, to promote private groundwater development as feasible, to install and maintain drainage as necessary and to complete ongoing investments. Over time, as such possibilities are exploited, further investment in storage will become important and needs to be planned and prepared now. Timing of such initiatives varies by region. The Narmada development program serving arid and water short western areas is already opportune, whereas in the great majority of states elsewhere, ample other opportunities for improving the productivity and extent of irrigated agriculture exist. Development of storage based schemes poses important land use, environmental and resettlement problems which need to be well handled to minimize negative impacts (Chapter VI).

Inter-Basin Water Transfers

2.32 Recognizing that water resources for further development will become critical in some basins (Krishna, Pennar, Madras Composite, South Tamil Nadu Composite in the south and Indus and Upper Ganga in the northwest) before the end of the century, the CWC (1980) has prepared conceptual plans for inter-basin water transfers from basins with perceived potential surpluses into water short basins. The possible basin transfers are summarized below:

(a) interlinking of the Mahanadi, Godavari, Krishna and Pennar river systems with up to 19 BCM/yr Mahanadi water and 19 BCM/yr of Godavari water transferred to the water short southern basins;

(b) interlinking of west coast rivers from north of Bombay to south of Tapi river with water transfers across the Tapi and Narmada rivers into mainland Gujarat and Saurashtra and for use in coastal Maharashtra. The entire scheme might mobilize up to 5.7 BCM/yr.;

(c) interlinking of Ken river with Chambal river in the southwest Ganga basin to transfer 2.5-3 BCM/yr into the Chambal sub-basin;

(d) diversion of west flowing rivers from the Western Ghats in Kerala across the divide into the water-short basins of southern India; and

(e) interlinking of the Brahmaputra to the Ganga by a canal sized at about 2830 m^3/sec originating at a barrage on the Brahmaputra at Jogighopa in India, crossing Bangladesh and tailing into the Ganga above Farakka barrage.

2.33 The set of schemes, apart from the Brahmaputra-Ganga link, was very roughly estimated by CWC to cost Rs. 500 billion (US$ 41.7 billion) in 1980 prices. Even the schemes involving only Indian territory are fraught with huge inter-State agreement problems and the potential reservoirs to make the schemes feasible are, in many cases, still to be identified, particularly with regard to transfers from the Western Ghats. While a small part of the east coast basin transfer scheme has been initiated by Andhra Pradesh to transfer Godavari water from Polavaram barrage to the Krishna, and small linkages are in place from the Upper Krishna basin into Pennar basin, basin transfer schemes on the scale envisaged above appear to be relegated to the distant future, even if more detailed investigation indicates their technical feasibility. Nevertheless, in view of regional development considerations and the uneven distribution of water resources in India, the technical and economic viability of such possible options should be further investigated, and promising prospects for the longer term should be assessed and prepared in further detail.

E. Regional Prospects

2.34 As discussed in sections A and B above, great caution must be employed in using the 1981 estimates of development potential. It has been emphasized by both Government and in this Review that the 1981 estimates of ultimate irrigation development potential of 113.5 million hectares (excluding further potential from river basin transfers) are likely to overestimate actual ultimate potential, exclusive of river basin transfers, due to difficulties in capturing seasonally concentrated available water, probable overassessment of combined groundwater and surface water resources, and the still small but increasing water needs for other uses. Even larger cautions may apply to regional or state breakdowns. As indicated in para 2.6, despite the greater understanding achieved as a result of the joint Bank/GOI review in 1990, detailed river basin plans will be needed to achieve a new precise quantitative statement of development potential on a regional basis.

Regional irrigation and drainage development prospects are discussed next, with due caution applied in interpreting the official estimates of potential by state provided in Tables 2.3 to 2.5. More detailed discussions by states is in Annex II (paras 28 to 47 and Table 3).

2.35 Northwest. Only very limited extension of irrigated area is possible in the northwestern states of Punjab and Haryana where potential is virtually fully utilized especially in Punjab. The Second Punjab Irrigation and Drainage Project (Cr. 2076/Ln. 3144) will complete the marginal extensions remaining for the surface schemes, improve efficiency of surface water delivery and management and improve groundwater drainage. Some additional surface water is feasible for Haryana if storages are constructed in the Uttar Pradesh hills. Additional groundwater development is possible in localized areas of Haryana, while in Punjab groundwater is already highly developed or overdeveloped in almost the entire area. The major additional investment over the next 30 years in southwest Punjab, Haryana and localities of adjoining states will need to be on surface and groundwater drainage to combat increasing waterlogging and soil salinization.

2.36 West. The western states of Rajasthan, Gujarat and Maharashtra have moderate remaining irrigation development potential; indicated as up to some 6.8 million hectares between them (but representing only 14% of total net cultivated area) as at 1985 on the basis of the 1981 estimate of ultimate irrigation potential. The bulk of the surface irrigation development possibilities are represented by incomplete ongoing projects and the Narmada project (about 2 million hectares), the latter being particulary important for Gujarat. Groundwater development potential is present in all three states, especially Maharashtra, but may represent only about 25% of the total remaining irrigation development potential. A regional feature is that both existing and potential irrigation is localized leaving large areas still dependent on rainfed farming possibilities. Under good irrigation, incremental yield response can be high given the marginal conditions of rainfed farming in much of the area.

2.37 East and Central. The largest irrigation development potential is found in eastern and central India. Between them, Uttar Pradesh, Bihar, West Bengal, Orissa and Madhya Pradesh may have up to 25 million hectares (1985, based on the 1981 assessment of ultimate potential) of remaining potential for future development, with Uttar Pradesh, Bihar and Madhya Pradesh each having over 13% of India's remaining potential. The five states may between them have about 56% of India's remaining potential. Some 40% of future potential was estimated to be in the form of groundwater. Good groundwater development prospects exist in all these states. Together with improved water management on existing surface irrigation schemes and investment in drainage, groundwater development should be the hub of future irrigation and drainage development strategy in eastern and central India. Groundwater development needs to be focussed on areas where exploitation would not adversely affect dry season Ganga river flows. Such favorable areas are those where the water table is high and which tend to be subject to monsoon waterlogging. Further development of groundwater irrigation should emphasize private tubewells (and dugwells where feasible in rock underlain hilly areas of Madhya Pradesh, Orissa and West Bengal) rather than public tubewells for which performance has usually been disappointing (Volume I, para 1.45). A solution would be required to the problem of low investment capacity for many farmers in these states.

2.38 As concerns the public investment program, completion of ongoing projects has a high medium term priority particularly in states such as Madhya Pradesh and Orissa. Further expansion of surface irrigation, particularly in Uttar Pradesh, will require creation of additional storage, but there is much to be done to improve performance of existing irrigation and drainage before considering embarking on this. A major emphasis in all of these states needs to be placed on improving water management on existing schemes to provide a more equitable and reliable water supply better geared to the agricultural needs of eastern and central India (para 1.31). Given the large dimension of the existing surface irrigation network in these states, an approach involving a

low investment cost per hectare (e.g., the NWMP approach) would achieve much greater impact than more costly modernization efforts which for budgetary constraints could not cover a large area. Of much greater relevance in the medium term than new irrigation projects, are the opportunities of reducing risks and improving kharif yields through investments in surface drainage and flood protection. Simple surface drainage investments have low investment costs relative to new irrigation and may provide larger impact than supplemental irrigation in the kharif season, especially in those areas where the problem is excessive rather than insufficient water. Tackling the Usar land problem (saline and sodic soils) in Uttar Pradesh, which may affect some 2.5 million hectares, is also needed in the localities affected.

2.39 The above commentary needs, however, recognition of some important implementation constraints. Thus, while irrigation investment opportunities in eastern and central India are large, performance of most surface irrigation systems is very deficient; investment costs have risen considerably and both water management and maintenance is poor. Until public sector management of existing irrigation improves, it may be questioned as to whether yet further investment in surface schemes is justifiable. While poverty impact and the strategic importance of good agricultural growth from eastern and central India weigh in favor of investing in irrigation and drainage in this region, the yield impact of such investments is still well below its potential. Higher productive impact from surface irrigation investments is achievable in drier regions such as the south and west. In large part, climate influences the level of incremental impact achievable under irrigation (larger impact in drier zones), and higher rainfall also complicates water management (Volume I, para 4.10). Management performance, however, is an additional factor and eastern and central India have particular need for high quality performance given that both the technical problems facing irrigated agriculture and the gross potential for expanding irrigation are greatest in these states.

2.40 South. The southern states of Andhra Pradesh, Karnataka and Tamil Nadu have only moderate scope (poor in Tamil Nadu) for future expansion of irrigation. Based on the 1981 estimate of ultimate development potential, as of 1985, a further 6.5 million hectares of potential remained to be developed (14% of India's future development potential) on top of the 11.2 million hectares already developed in southern India (Table 2.3). Over half of the future development potential was estimated to be in Andhra Pradesh, while Tamil Nadu was estimated to have virtually fully developed its water resources. Our updated assessment would indicate that the proportional distribution of development prospects between the three states remains valid though the magnitude of future prospects is likely to be overstated. The situation in Tamil Nadu is that virtually the entire water resources of the state are utilized while the demands of conurbations such as Madras are increasing. Some scope for additional localized groundwater irrigation is possible and some expansion of surface irrigated area may be possible through better economies in usage of water on existing surface commands which could thus be expanded in area. In Andhra Pradesh and Karnataka, completion of ongoing projects forms the bulk of remaining development potential for surface schemes, the other priority being to improve water management of existing schemes. Some potential for creation of additional storage on the Godavari is present in Andhra Pradesh. Moderate scope exists in both states for additional groundwater development. Investment in drainage may be attractive in irrigated areas, especially on the delta schemes prone to waterlogging and floods. As in the western states, distribution of existing irrigation and future prospects is localized in the southern states and over half of net sown area is likely to remain unirrigated even when full development of state water resources is achieved. Further expansion of irrigation in southern India would depend on the technical and economic feasibility of water transfers from surplus basins further north and across the Western Ghats from Kerala.

F. River Basin Planning

2.41 The natural hydrological unit for planning water-resource development is the river basin; i.e., the entire area of the watershed which contributes to the natural drainage system. Within this area, both the surface water and groundwater resources are parts of the hydrological system and their use must be planned conjunctively. Any action which modifies the hydrology in an upstream part of the basin will affect the water availability in the downstream part of the basin. Similarly, actions which change the flow pattern of the groundwater system can have repercussions on surface water flows. Actions which modify the chemical and/or biological characteristics of the water resource in the upper basin will have an impact on downstream users, which can be important in the case of waste waters discharged to the rivers from urban or industrial areas. Only one of India's 18 major river basins is contained in a single state. India's "National Water Policy" recognizes the importance of basin planning of water resources but lack of coordination between states has severely limited its implementation. Improvements in data collection and planning and improved coordination between states and between different uses of water is, however, essential if India is to effectively develop its water potential.

2.42 In this regard, the National Water Policy with updating as appropriate should be reaffirmed as a policy guide. Based in part on this document, the following actions are recommended:

(a) Increased emphasis by state and central governments on data collection to better assess water resources, monitor resource use and revise as appropriate current estimates of irrigation development potential;

(b) Establishment of River Basin Planning Commissions for all of India's major river basins;

(c) Preparation of river basin plans for decision making on water and irrigation development;

(d) Where useful, further creation of autonomous irrigation/water development Boards or Authorities for water and irrigation development and operations where more than one state or usage of water is involved. This has been done with good effect in cases such as the Bhakra-Beas Management Board (sharing of irrigation water between Punjab, Haryana and Rajasthan);

(e) Preparation by each state of a "State Water Policy" fitting in the framework of the National Water Policy and the river basin plans. The center should only clear use of central plan funding for projects prepared in the framework of the National Water Policy;

(f) Improve central coordination. Establish a senior level inter-ministerial water policy committee and combine, or at least better coordinate, the roles of CWC and CGWB; and

(g) Amend the constitution to make water and irrigation development policy a "concurrent subject." Development of water resources would then come under both central and state jurisdiction, and no state would be in a position to apportion to itself all the water resources in its borders without the center's concurrence. Amendment may take time, but would be an important underpinning for policy and future decisions, especially over the longer term. The measures above can be expedited without waiting for this adjustment.

Table 2.3 Indicative Irrigation Development Prospects by Major States (as estimated from Government statistics at 1985 based on 1981 estimates of ultimate irrigation potential)*

State	Ultimate Development Potential ('000 ha)	Potential Already Developed ('000 ha)	(%)	Potential Remaining to be Developed ('000 ha)	(% of total)
Northwest					
Punjab	6550	5636	(86)	914	2.0
Haryana	4550	3316	(73)	1234	2.7
	11100	8952	(81)	2148	4.7
West					
Rajasthan	5150	3799	(74)	1351	3.0
Gujarat	4750	2938	(62)	1812	4.0
Maharashtra	7300	3697	(51)	3603	7.9
	17200	10434	(61)	6766	14.9
East and Central					
Uttar Pradesh	25700	18803	(73)	6897	15.2
Bihar	12400	6301	(51)	6099	13.4
West Bengal	6110	3299	(54)	2811	6.2
Orissa	5900	2628	(45)	3272	7.2
Madhya Pradesh	10200	3794	(51)	6406	14.1
	60310	34825	(58)	25485	56.1
South					
Andhra Pradesh	9200	5608	(61)	3592	7.9
Karnataka	4600	2397	(52)	2203	4.8
Tamil Nadu	3900	3194	(82)	706	1.6
	17700	11199	(63)	6501	14.3
Remaining India	6990	2465	(35)	4525	10.0
Total India	113300	67875	(60)	45425	100.0

Source: Annex 2, Tables 8 & 9 based on GOI/CWC estimates.

* **Note: As discussed in para 2.34, actual potential is likely to be less than indicated by these estimates.**

Table 2.4 Indicative Prospects for Future Development of Major and Medium Surface Irrigation (as estimated by Government at 1985 based on 1981 Estimates of Ultimate Irrigation Potential)*

State	Ultimate Development Potential ('000 ha)	Potential Already Developed ('000 ha)	(%)	Potential Remaining to be Developed ('000 ha)	(% of total)
Northwest					
Punjab	3000	2462	(82)	538	1.9
Haryana	3000	1929	(64)	1071	3.8
	6000	4391	(73)	1609	5.7
West					
Rajasthan	2750	1812	(66)	938	3.3
Gujarat	3000	1264	(42)	1736	6.2
Maharashtra	4100	1700	(41)	2400	8.6
	9850	4776	(48)	5074	18.1
East and Central					
Uttar Pradesh	12500	6813	(55)	5687	20.3
Bihar	6500	2879	(44)	3621	12.9
West Bengal	2310	1587	(69)	723	2.6
Orissa	3600	1568	(44)	2032	7.3
Madhya Pradesh	6000	1802	(30)	4198	15.0
	30910	14649	(47)	16261	58.1
South					
Andhra Pradesh	5000	3268	(65)	1732	6.2
Karnataka	2500	1269	(51)	1231	4.4
Tamil Nadu	1500	1244	(83)	256	0.9
	9000	5781	(64)	3219	11.5
Remaining India	2740	900	(33)	1840	6.6
Total India	58500	30497	(52)	28003	100.0

Source: Annex 2, Table 8 & 9 based on GOI/CWC estimates.

* **Note: As discussed in para 2.34, actual potential is likely to be less than indicated by these estimates.**

Table 2.5 Indicative Groundwater Development Prospects by Major States (as Estimated from Government Statistics at 1985 based on 1981 Estimates of Ultimate Irrigation Potential)*
(Billion Cubic Meters/year)

State	Groundwater Available for Irrigation[a/] (BCM/yr)	Present Irrigation Usage (BCM/yr)	Balance for Future Exploitation (BCM/yr)	(% of total)
Northwest				
Punjab	15.3	15.2	0.1	0.1
Haryana	7.2	5.1	2.1	0.8
	22.5	20.3	2.2	0.9
West				
Rajasthan	13.3	5.0	8.3	3.3
Gujarat	19.2	6.4	12.8	5.1
Maharashtra	32.1	7.0	25.1	10.0
	64.6	18.4	46.2	18.5
East and Central				
Uttar Pradesh	68.4	25.0	43.4	17.4
Bihar	28.7	6.8	21.9	8.8
West Bengal	17.6	2.9	14.7	5.9
Orissa	19.8	1.0	18.8	7.5
Madhya Pradesh	50.8	6.0	44.8	17.9
	185.3	41.7	143.6	57.4
South				
Andhra Pradesh	36.9	7.4	29.5	11.8
Karnataka	13.8	5.0	8.8	3.5
Tamil Nadu	25.6	12.0	13.6	5.4
Kerala	6.9	0.7	6.2	2.5
	83.2	25.1	58.1	23.2
Total Major States	355.6	105.5	250.1	100.0

a/ After allowance of usage for community and industry purposes.

Source: Annex 2, Table 10.

* **Note: As discussed in para 2.34, actual potential is likely to be less than indicated by these estimates.**

Chapter III: Economic Viability

A. Background and Data Sources

3.1 While irrigation investments have had important impact on the basic productivity of the land, leading in turn to a substantial impact on agricultural growth, incomes and employment, (Chapter I) this has been achieved at major public expenditure cost. Since 1951, the combined Plan outlays from Central and state governments on major and medium irrigation project investments have totalled Rs. 673 billion in 1985-86 prices, and expenditures rose significantly in the Sixth and Seventh Plan Periods (Annex Table 3.1). Recent project completion reports indicate a rise in irrigation investment costs per hectare (real terms) that can also be inferred from Annex Table 3.1. As a percentage of state Plan outlays, investments in irrigation have amounted to between 24 to 38% in most states (Annex Table 5.4). Most government and externally funded projects have also encountered substantial implementation delays. Of particular importance, benefits have frequently been well below expectations. It is thus important to better understand the economic viability of this major development thrust, any changes that may be perceptible over time and the factors that make for viable or nonviable investments in the sector. Procedures used in India for evaluating the economic viability of irrigation investments will also be discussed.

3.2 Data on the performance and in particular the economic viability of irrigation projects in India is very limited. Projects funded by government use undiscounted benefit-cost ratios rather than economic rates of return in their analysis (para 3.18), and ex-post reviews of performance and economic viability are seldom performed. This exercise will therefore rely primarily on review of ERRs of World Bank funded projects. As available, Project Completion Report (PCR) and Operations Evaluation Department (OED) audits of PCRs will also be used.[1] These results are expected to be better than the results that have been obtained for solely government funded projects. Projects receiving World Bank financial assistance have the advantages of usually more thorough project preparation, greater selectivity in project choice, lower financing constraints during implementation, and closer scrutiny and technical assistance during implementation due to the combined efforts of central and state governments and the Bank. Notwithstanding, as indicated below, major preparation and implementation problems have been encountered even on these projects.

3.3 Some care must be employed in making judgments based on ERR comparisons. Output prices have varied considerably over time. Assumptions used at appraisal concerning project costs, impact on production and the project implementation period have frequently been widely divergent from the reassessment at project completion. With hindsight, a number of appraisals have materialized as far too optimistic. Further, several earlier PCRs are also observed to have been over optimistic in their assessment of eventual project benefits. Finally, some differences in methodology or in the degree of analytical sophistication used are also found; for instance, in shadow pricing and in the assumptions concerning whether output is an export or an import substitute. A further consideration is that the ERR, while a useful and readily understood guide for investment decisions, does not capture all of the benefits and costs of investment in infrastructure (para 3.16).

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[1] For all Bank-assisted projects, a Project Completion Report (PCR) is prepared at project closure. These are then submitted for independent review by the World Bank's Operations Evaluation Department (OED).

B. Economic Rates of Return from Irrigation

ERRs Estimated at Appraisal

3.4 Table 3.1 compares economic rates of return as estimated at appraisal for World Bank assisted projects that are either ongoing or have been recently closed. As calculated at appraisal, all ERRs were above the opportunity cost of capital of 12% usually taken for India, with most ERRs in the 15 to 30% range. The following observations emerge from the appraisal estimates:

(a) As to be expected, projects involving improvements to existing systems had higher appraisal ERR assessments than projects involving new investments. Improvement projects exclude sunk costs and have modest incremental costs relative to the incremental benefits that can be achieved. This is in particular illustrated by the National Water Management Project (Cr. 1770) involving low cost operational improvements. To a lesser extent, modernization and systems improvement projects, involving higher incremental costs per unit of improved command area served, also had good ERRs. As discussed by Daines and Pawar (1987), the viability of higher investment cost improvements depends on achieving higher levels of output. Investment in linings or more sophisticated control systems can, where the particular situation justifies this, achieve the necessary higher levels of performance, but the assessment, particularly for investment in linings, needs careful consideration on a case by case basis.

(b) New surface irrigation investments had typically more modest appraisal ERRs, generally in the range of 15 to 20%.

(c) The three public tubewell projects[2] had appraisal estimated ERRs of 30% or above. Based on observed performance and impact of these projects, rates of return are now expected to be substantially lower. Expected command areas, water pumping and irrigation intensity have been much lower than anticipated, with corresponding impact on incremental production. A mid-term re-evaluation of the ERR of the Indo–Dutch public tubewells project in Uttar Pradesh (modelled after the World Bank project) yielded a 9% ERR compared with 30% estimated at appraisal.[3] Based on recent analysis of the Bank assisted project in Uttar Pradesh, a large reduction in the ERRs of the three ongoing Bank projects in east and central India is also anticipated.[4]

(d) Available analysis and field observations demonstrate the high economic viability of private shallow tubewells powered by small diesel or electric pumps. Daines and Pawar (1987) estimated ERRs in excess of 30% in eight out of nine evaluations

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[2] Deep tubewells serving a group of farmers in a command area of up to 100 ha and constructed and managed by government.

[3] Economic and Financial Appraisal, Indo-Dutch UP Tubewell Project, Evaluation Unit Working Paper No. 2, May 1989.

[4] Uttar Pradesh Groundwater Development, Issues and Options, Agriculture Operations Division, World Bank, February 1991.

reviewed.[5] The Indo-Dutch evaluation unit (op cit) estimated that the ERR of a project comprising private diesel powered shallow tubewells would be 33%. These results are consistent with field observations and financial farm budget analysis of private electric or diesel powered shallow tubewells in eastern and central India, and field observations elsewhere. Incentives for farmers to invest in such wells are high and remain good even after removal of subsidies (World Bank, 1991, op. cit). This is because farmers have individual control over water and the production constraints posed by water management problems on most surface irrigation schemes are not present. As a result, yields are generally good to very good, more than making up for the higher costs to the farmer of water provision from groundwater sources. This explains the rapid spread of private groundwater irrigation in the past several decades, especially in northern India, with its generally easily accessible aquifers.

(e) Not analyzed here are more advanced on-farm irrigation systems such as drip and sprinkler irrigation which could use groundwater or on-farm storage of part of surface supplies as a water source. These systems are being promoted by private equipment suppliers and, while still infrequently found, are being rapidly adopted by farmers indicating viability and anticipated much greater importance over time.

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5 Some of the ERR estimates for electric tubewell development reviewed by Daines and Pawar appear to have inadequately costed the full cost of provision and distribution of power. This adjustment is still expected to yield good ERRs (World Bank, 1991, op cit). Additionally, in areas where groundwater irrigation is based on recharge from surface irrigation, the economic viability of both surface and groundwater irrigation should be assessed together.

Table 3.1 Economic Rates of Return as Estimated at Appraisal for Ongoing or Recently Completed World Bank Assisted Irrigation Projects

	Project Name	Project Number	ERR %
A.	New Surface Irrigation Projects		
	Major Projects		
	Mahanadi Barrages (Orissa)	Cr. 1078-IN	21.0
	Narmada Dam (Gujarat)	Cr. 1552-IN/Ln. 2497-IN	15.0
	Subernarekha Projects (Bihar and Orissa)	Cr. 1289-IN	17.3
	AP Composite and CAD	Ln. 2662-IN	15.0
	Narmada Canal (Gujarat)	Cr. 1553-IN	12.0
	M.P. Major	Cr. 1177-IN	21.0
	Upper Krishna II (Karnataka)	Cr. 2010-IN/Ln. 3050-IN	13.0
	Maharashtra Composite III	Cr. 1621-IN	20.0
	Medium Projects		
	M.P. Medium	Cr. 1108-IN	18.0
	Gujarat II	Cr. 1011-IN	18.0
	Orissa Medium	Cr. 1397-IN	19.0
	Minor Projects		
	Karnataka Tanks	Cr. 1116-IN	20.0
B.	Groundwater Development (Public tubewells)		
	Second UP Public Tubewells	Cr. 1332-IN/Ln. 124-IN	29.8
	Bihar Tubewells	Cr. 1737-IN	33.0
	W. Bengal Minor (mainly public tubewells)	Cr. 1619-IN	37.0
C.	Modernization and Systems Improvement		
	Kallada Irrigation (Kerala)	Cr. 1269-IN/Ln. 2186-IN	20.0
	Upper Ganga Modernization	Cr. 1483-IN	19.0
	Periyar Vaigai II	Cr. 1468-IN	15.0
	Haryana Irrigation II	Cr. 1319-IN	29.0
	Punjab Irrigation II	Cr. 2076-IN/Ln. 3144-IN	20 to 33a/
	MP Chambal II	Cr. 1288-IN	35.0
D.	Operations Improvement		
	Maharashtra Water Utilization	Cr. 1383-IN/Ln. 2308-IN	35.0
	National Water Management Project (NWMP)		
	(i) Vanivitas Sagar (Karnataka)	Cr. 1770-IN	45.0
	(ii) Sathanur (Tamil Nadu)	Cr. 1770-IN	43.0
	(iii) Rajah Banda (Andhra Pradesh)	Cr. 1770-IN	29.0

a/ Different components.

ERRs Estimated at Project Completion

3.5 Economic rates of return as estimated at project completion are in Tables 3.2 and 3.3. Table 3.2 is from OED's database on completed irrigation projects submitted to OED between 1974 to 1988. It should be noted that the OED review process involves recalculation of ERRs on a selective basis, with most ERRs taken without recalculation from the PCR reassessment. For that period, PCR results were generally satisfactory despite the fact that for about half of the projects, cost overruns of more than 50% were incurred. Escalation of output prices during project implementation appears to have offset such cost increases on a number of projects. This favorable influence of world price movements is in contrast to the negative impact of price shifts for many projects evaluated more recently (para 3.7).

Table 3.2 Estimated ERRs of Completed World Bank Assisted Irrigation Projects in India: 1970-1984

Name	OED ID	Year of Approval	Year of Actual Completion	Year of Re-eval.	Est Cost US$ M (Appraisal)	Actual Cost (Comp)	Est ERR (App) %	Actual ERR a/ (Comp) %
Kadana	C0176	1970	1978	1981	66.7	183.5	14	12
Pochampad	C0268	1971	1979	1981	127	211	14	14
Rajasthan Canal Command Area	C0502	1974	1983	1986	174	174	25	30.5
Godavari Barrage	C0532	1975	1983	1982	69.9	87.5	44	60.5
Chambal Command Area	C0562	1975	1981	1983	46.6	43.4	22	21
Periyar Vaigai	C0720	1977	1984	1986	45.6	50.7	20	21
Maharashtra Composite Irrigation I	C0736	1977	1984	1985	140	183.4	17	17
Orissa Irr.	C0740	1977	1983	1985	116	116	20	19
Karnataka Irrig. (RD)	C0788	1978	1987	1988	284.4	478.6	16	10
Gujarat Med. Irrigation	C0808	1978	1984	1987	170.5	344.1	20	30
Haryana Irrigation	C0843	1978	1983	1985	222	222	32	25
Maharastra Irrigation II	C0954	1979	1986	1988	452.9	496.2	15	1
U.P. Tubewells	C1004	1980	1983	1986	37.7	37.7	36	26

a/ Several projects are currently being re-evaluated by OED and lower completion ERRs are anticipated.

Source: Database on Irrigation Projects Audited, 1974-1988, Operations Evaluation Department, World Bank, 1990

Table 3.3 Comparison of Appraisal ERRs and Re-estimated ERRS at Project Completion for Selected World Bank Assisted Irrigation Projects in India

Project	Appraisal ERR	(ERR %) Re-Estimated ERR Based on PCR
1. Mahanadi Barrage (Orissa)	21.0	14.1
2. Subernarekha (Bihar and Orissa)	17.3	7.2
3. Gujarat II	18.0	3.2
4. Andhra Pradesh Irrigation and CAD	15.0	3.2
5. M.P. Chambal II (Modernization)	35.0	9.9
6. M.P. Medium	18.0	5.1
7. Kallada Irrigation and Tree Crops	20.0	7.2
8. Karnataka Tanks	20.0	3.6

Source: Project Completion Reports prepared in 1989.

3.6 Of much greater concern are the ERR results shown in Table 3.3 from PCRs undertaken in 1989. Of eight reassessments, only one project had a re-estimated ERR greater than 12% and four projects had ERRs of 5% or less[6]. One encouraging recent result, however, was the audit of the Punjab Irrigation Project which had a re-estimated ERR reported by OED in 1989 to be greater than the appraisal estimate of 36%.

3.7 The very different ERR estimates reported at completion for the 1989 PCRs prompts obvious questions concerning the meaningfulness of the ERR appraisal estimates in Table 3.1 and whether there has been a downturn in project performance during more recent years. As discussed by OED in its 1989 Review of Agricultural (including irrigation) Projects across countries, one factor has been the substantial fall in world rice prices in the mid 1980s. For many of the more recently re-evaluated projects, a much lower price for rice was operative at project completion stage than was used at appraisal. This may partly explain the generally poor performance across countries of irrigation projects audited in 1989 as shown in Annex Table 3.4, though important project specific deficiencies have also been noted by OED.[7]

3.8 In the case of India, while the decline in world rice prices in the mid 1980s has been an influencing factor, implementation problems have been the primary influence (Annex Table 3.5). In seven of the eight projects re-evaluated at completion in 1989, capital investment costs had increased substantially in real terms over appraisal estimates, with cost increases ranging from 49%

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[6] In ex-post analyses of government financed projects, generally completed at slightly earlier periods (para 3.5), Daines and Pawar also found disappointing results. Only two out of fourteen projects examined had ERRs greater than 12% (Annex Table 3.2).

[7] Annual Review of Evaluation Results for 1989; Agriculture and Rural Development Sector. OED, March, 1990.

to 147%. Seven projects experienced implementation delays. For two projects, the PCRs reduced the command areas expected to be irrigated and for one project the appraisal assumed cropping pattern was adjusted.

3.9 These statistically observed implementation deficiencies (project delays, cost overruns, reduced command areas and lower productive impact) are themselves the product of a variety of institutional and technical deficiencies. Project design has often been based on incomplete base data and analysis and inadequate detailed sequencing of works. Appraisal has sometimes preceded completion of detailed design. Weak institutional capabilities have caused delays and poor implementation of construction. The performance of irrigation and agriculture departments in operations and maintenance of completed works and provision of agricultural extension services has usually been very inadequate.

3.10 Despite the better PCR results in earlier years, there is no firm indication that technical performance was appreciably better then. For example, half of the projects completed between 1970–84 overran appraisal cost estimates by 50% or more. Moreover, project completion reports at that time did not take into account that yields and actual irrigated area was likely to be smaller than assumed at appraisal. This adjustment is always difficult to assess at PCR stage as the micronetwork is seldom complete at completion of disbursement against major works when PCRs are prepared. With the further passage of time, it is now evident that on a number of projects this is likely to be the case. Rising rice prices in that period also improved PCR rate of return estimates. Based on field observations and analysis of the methodology used for calculating earlier completion report ERRs, the most reasonable conclusion is that project performance and resultant economic viability has been poor all along for most projects. There are, nevertheless, some trends of particular concern. Construction quality and maintenance standards have deteriorated over the past two decades and water management has been critically deficient on most surface schemes. Institutional performance has also deteriorated (Volume I, Chapters IV and V).

C. Implementation and Investment Implications

3.11 Without urgent addressment of the array of technical and institutional problems besetting the irrigation sector in India, the economic viability of most irrigation and drainage investments, already modest to poor, will not improve and may get worse. There is also a need for more thorough project preparation and for greater realism concerning expected performance and yield impact when assessing the likely viability of an irrigation investment during the preparation and appraisal process.

3.12 The most important conclusion is that much better implementation performance is essential if irrigation projects are to be economically viable. A key government priority is to address the main technical and institutional shortcomings leading to such performance shortfalls (Recommendations in Volume I).

3.13 Secondly, ERR results indicate the investment directions to take to increase the economic viability of irrigation investments. The two most attractive investment options are investment in private groundwater development and improvements in water management. Selectively chosen modernization of existing irrigation systems and completion of ongoing irrigation projects are also attractive due to the sunk costs already incurred and incremental benefits achievable relative to the costs of improvement or completion. Additionally, the above ERR analysis does not cover other opportunities assessed to have good economic returns: drainage (selective where needed), viable

land rehabilitation (e.g. usar lands), applied irrigation technology and irrigated agriculture research, and agricultural and water management extension (Vol. I, paras 1.43 to 1.48).

3.14 Thirdly, while better project preparation and implementation can improve the economic viability of new irrigation investments, all indicators point to modest economic returns from investments in new surface irrigation projects. Appraisal estimates of rates of return of typically 12 to 20% have proven overoptimistic. A more realistic general expectation for India concerning future investments would be for moderately well performing new surface irrigation projects to yield ERRs of between 5 to 10% and for excellent performers or projects with particularly advantageous features to yield between 10 to 15% ERRs.

3.15 Are such returns acceptable? Clearly, they are lower than returns from groundwater development and from systems improvement. They are also lower than returns from investment in commercial agriculture (e.g., dairy, sericulture, some agroindustries) and the anticipated impact from investment in support services such as extension and research. At the level of marginal investment analysis - where to put the next dollar - the answer would appear to be negative. Within the irrigation sector, there are many more attractive priorities in the short and medium term than embarking on new investments: improving the performance of existing surface irrigation systems; private groundwater development; investment in drainage; and completing the very large backlog of uncompleted projects. There is also the urgent need to improve maintenance and to rehabilitate deteriorated infrastructure.

3.16 The issue of moderate to low ERRs for new investments in surface irrigation, even where implementation performance is reasonable, will have to be faced in the longer term. Indeed, in some regions this situation has already arisen.[8] As discussed in Chapter II, increased exploitation of India's seasonally concentrated water runoff will require investment in water storage. Further, in many regions increased groundwater development is not feasible except in conjunction with aquifer replenishment from a surface irrigation scheme. For the long term, or in some regions where water scarcity is already present and alternative more viable opportunities for investment in water exploitation are not available, investment in storage based water provision schemes is necessary. Evaluation of such investments needs to take account of the broader development impacts that water and provision of irrigation provide, and that are not fully captured in ERR analysis. Provision of water is a basic infrastructural need in the development process, with multiple uses and benefits. As concerns irrigation, beyond the first round benefits captured in ERR analysis, there are longer term secondary impacts on agricultural productivity and multiplier impacts on non-farm employment (Chapter I). The success story of agricultural development in the northwest - a semi-arid region suitable under rainfed conditions for a single water-stress tolerant annual crop (e.g., millet, sorghum, cotton) or for extensive grazing - was made possible by the major development of surface irrigation in the 19th and early 20th centuries. Subsequent developments - the rapid spread under the green revolution of HYVs, fertilizer usage and groundwater development (based on water provisions to groundwater provided by irrigation and used conjunctively with surface irrigation) - could not have taken place if the irrigation infrastructure had not been there and functioning well. Multiplier impacts from agricultural development are also important. A 100 rupee increase in agricultural income stimulates 105 rupees of additional output in manufacturing and 114 rupees of additional tertiary sector output, a total nonfarm output multiplier of 2.19 (Hazell and Haggblade, 1989). Such broader development perspectives will need to be taken account of in decision making for medium and longer term development of India's water resources. Nevertheless, an essential requirement for any project is good implementation, and no investment can be justified in a situation where poor implementation

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[8] For instance, water resource development for arid western India and some southern states.

is a likelihood. Regrettably, based on past performance, this is the case in many states.

3.17 A fourth issue concerns the implications for irrigation system design of the cost of investment in irrigation. A realistic (1991 prices) cost estimate for a new surface irrigation system would typically be around Rs 70,000 per hectare of command area created (US$3,900). In terms of, for instance, paddy this represents the value of over 20 tons of incremental paddy. Discounting must also be employed and O&M and farm production costs entered in the cost streams. This will necessarily mean that irrigation systems must be designed to have significant incremental impact on productivity if they are to be economically viable. India's past policy has been to try to spread the benefits of irrigation over a large area entailing higher costs for the distribution network and lower intensity of water usage per hectare. Some observers anticipate that this practice has overextended irrigation systems reducing yield impact and increasing costs and resulting in reduced economic viability. Further analysis is recommended on this issue. Additionally, at the design stage for each project, the economic viability of the project under different degrees of water spreading should be assessed.

D. Improving Project Preparation and Evaluation

3.18 The prospects for effective and viable investments in Indian irrigation would be greatly improved if project preparation was much more completely and comprehensively handled including economic evaluation based on more realistic assumptions. Unlike the industrial and other infrastructure sectors in India, where calculation of economic rates of return has become standard procedure, irrigation investments are evaluated on the basis of undiscounted benefit: cost ratios. The cut-off benefit: cost ratio used for irrigation is 1.5:1, with a ratio greater than 1:1 accepted in drought prone areas. Prices used are financial. Sensitivity analysis is rarely performed. These estimates are calculated at the end of the project preparation period rather than as a decision making aid during project identification and when evaluating design alternatives. Common procedures when estimating such ratios are to ensure that the project passes the viability test by inflating benefits or underestimating costs. Despite a lengthy multistage clearance process involving a number of government departments at both state and central level for all major projects, scrutiny of key technical assumptions is often weak. Economic and financial evaluations are also weak due to the critical absence in state irrigation departments and in GOI's Central Water Commission (CWC) of staff qualified in these disciplines.

3.19 An equally important need is to improve the quality of technical preparation. Pressure to invest in irrigation has led to Government financing of investments without first undertaking a full project preparation exercise based on adequate hydrological, agronomic and socio-economic data, and without completion of a detailed and costed component by component technical design. Finally, irrigation investment decisions need to be based on a pipeline of already prepared projects so that selectivity can be employed. It is also important to increase the public accountability of investment decisions in irrigation and to better utilize academic institutions in project analysis and monitoring. These problems have had important impact on the quality and viability of irrigation investments in India. They can be commonly observed in relation to government financed projects, and have also had influence on projects financed with external (including World Bank) assistance. The following improvements are recommended as an essential concomitant to further investment in irrigation:

(a) Establishment of an upgraded project preparation and appraisal staff capability in each state irrigation department and at the level of CWC. This would involve more thorough technical analysis, funding of physical and socio-economic data collection, staff training and use of consultants;

(b) Building up a pipeline of irrigation and drainage project proposals focussing in the short and medium term on the most attractive options identified in part B above;

(c) Usage of more rigorous guidelines for technical preparation of irrigation and drainage investments;

(d) Revision of the methodology for economic evaluation of projects based on standard discounted cost-benefit criteria (ERRs or Discounted Net Benefit : Cost Ratios);

(e) Establishment or, where existing, strengthening of project monitoring and evaluation units in state irrigation departments and CWC;

(f) Contracting out of part of monitoring and evaluation work and special impact evaluation studies to consultants and universities; and

(g) Standard distribution to local and selected national universities of all project preparation reports and monitoring and evaluation studies, to increase the public accountability of decision making and implementation performance.

Chapter IV Potential Agricultural Growth Influences from Irrigation

4.1 This chapter will explore the future contribution that irrigation can make to agricultural growth. Projections based on different assumptions will be used to discuss the implications of different growth rates of irrigated and rainfed agriculture. Within the irrigated agriculture subsector, the respective potential contributions of irrigated area expansion and productivity growth will be examined. None of the illustrative projections made are intended to be predictive. Rather, the discussion is intended to highlight several key technical influences on agricultural growth and the respective contributions that can be achieved from productivity growth of irrigated agriculture, area expansion of irrigation and productivity increases from rainfed agriculture. It must also be emphasized that the broader influences on productivity are not discussed. For instance, changes in the productivity of agriculture, while importantly based on changes in farm technology, and (in the case of irrigation) water management and irrigated area expansion, are also influenced by the structure of incentives and other factors such as land tenure, other infrastructure and services.[1]

A. Sources of Agricultural Growth

4.2 Past agricultural growth, at about 2.5% per annum has been made up of expansion in net farmed area and improvements in productivity; increased average cropping intensity per unit of land, improvement in yields, and diversification to higher value crops. Since the early 1970s, a virtual ceiling has been reached on available land for expansion of arable area (Table 4.1). Hence, future growth will depend almost entirely on productivity growth of rainfed agriculture, increased productivity on irrigated lands and expansion of irrigated area.

4.3 As discussed in Chapter I, past agricultural growth has relied heavily on the expansion of irrigation and the "green revolution" technology which was largely confined to irrigated lands (and, more specifically, to regions and irrigation systems where successful water management was achieved). Under irrigation and the new technologies, yields were increased (though impact was very variable) and in some areas and irrigation systems more than one crop was feasible. Diversification impact is more difficult to assess (paras 1.17 to 1.21), but will clearly be an important factor for the future based on agricultural growth studies in other countries.

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1 For such broader discussion, refer to "Agriculture: Challenges and Opportunities"; Volume II of India, 1991 Country Economic Memorandum (Agriculture Operations Division, India Department, World Bank, April 29, 1991).

Table 4.1 Growth of Cultivation and Irrigation
(million ha)

	Unit	1951/52	1965/66	1970/71	1984/85
Net Cropped Area	M ha	119.4	136.2	140.3	140.7
Gross Cropped Area	M ha	133.2	155.3	165.8	175.9
Area Cropped More than once	M ha	13.8	19.1	25.0	35.2
Net Irrigated Area	M ha	21.0	29.3	31.1	41.8
Gross Irrigated Area	M ha	23.2	30.9	38.2	54.1
Implied Irrigation Intensity	%	110	105	123	129
Share of Gross Irrigated to Cross Cropped Area	%	17.4	19.9	23.0	30.7

Source: Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi.

Rainfed Agriculture

4.4 Concerning rainfed agriculture, some indication of its past growth impact can be ascertained from Table 4.2 which shows yield growth for crops that are mainly rainfed.[2] Productivity progress was overall quite limited through the 1980s. Apart from soybean (and cotton which was affected by expansion of cotton area under irrigation), all of these crops experienced yield growth of less than 1.5% per annum, and in several cases hardly any change is recorded. In aggregate, productivity growth of rainfed agriculture was probably not much greater than 1% and possibly below this. The limited progress of rainfed agriculture was mainly because good progress on varietal research had not been matched by water harvesting technology to conserve insitu soil moisture.[3]

4.5 Prospects for rainfed agriculture now look better based on the pilot results from the ongoing watershed development projects.[4] In particular, use of contour ploughing and vegetative bunds for arable crops and v-ditches and mulching for orchard crops provide scope for significantly improved water retention. For vegetative bunds, research and pilot projects with

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[2] Standard data reporting in India does not separate irrigated from rainfed yields or growth between irrigated and rainfed segments of agriculture.

[3] Rainfed agriculture prospects are discussed in more detail in the Agricultural Technology Review (Draft, Sept. 1989), India, Agriculture Operations Division, World Bank.

[4] A major emphasis on this technology is underway in the context of the watershed development projects assisted by the Bank. Following two pilot projects approved in the early 1980s, two larger projects -- Watershed Development Hills and Watershed Development Plains (Cr. 2100/Ln. 3175 and Cr. 2131/Ln. 3197) -- were approved in FY90.

vetiver grass are showing good impact on crop yields.[5] The new technology means that, for annual crops, susceptibility to drought periods during the rainy season can be reduced and the crop growing period extended due to longer retention of moisture by the soils. Coupled with use of shorter and more moisture stress tolerant varieties of cereals, pulses and other crops, research and pilot results over the last several years are indicating scope for significant yield improvement based on the combined use of water harvesting technology and the existing improved varieties. If these pilot results are further confirmed over a larger area during the next two to three years, a higher growth path for rainfed agriculture may be possible. Encouragingly, this technology is both easily replicable at farm level and involves very modest investment costs; the core of the new technology only involving the very simple and low cost practices of contour ploughing and vegetative bunding, coupled with use of short season varieties and some fertilizer.

Table 4.2 Past Changes in Productivity of Mainly Rainfed Crops [a/]

Crop	Average Yield for Triennium ending 1960/61 (kg/ha)	Average Yield for triennium ending 1986/87 (kg/ha)	Average Yield Growth per annum (%)	Proportion of Crop Area Irrigated 1986 (%)
Maize	892	1,290	1.5	NA
Sorghum	506	638	0.9	4
Pearl Millet (Bajra)	317	438	1.3	5
Chick Pea (Gram)	638	686	0.3	14
Pigeon Pea (Tur)	745	767	0.1	3
Groundnut	760	821	0.3	16
Cotton (Lint)	105	198	2.5 [c/]	26
Soybean [b/]	691	710	2.7	nearly all rainfed

a/ Crops grown wholly or predominately as rainfed crops. Extent of irrigated cropped area shown in the table. Yield averages include yields from irrigated crop areas.

b/ Practically no soybean was cultivated in 1960-61.

c/ Irrigation expansion was a likely important influence on yield growth for cotton. The percentage of cotton area irrigated in 1960-61 was 13%.

Source: Adapted from Agricultural Technology Review, Draft September 1989, Agriculture Operations Division, India Department, World Bank; based on MOA Directorate of Economics and Statistics data.

4.6 Aggregate growth of rainfed agriculture is nevertheless limited by the pace at which this technology can be replicated over a large area. It is also always constrained by the limitations of rainfall, even though water harvesting can substantially improve matters. For the 1990s, based on currently known technology and dissemination rates, the pace of aggregate yield growth of rainfed agriculture will probably not exceed 1.5% per annum and a 2% aggregate growth rate would be a very optimistic assumption.

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5 Refer "Vetiver Grass, A Method of Vegetative Soil and Moisture Conservation" (R.G. Grimshaw and J. C. Greenfield, 1987, ICARUS/P.S. Press Services, Delhi); and "Vetiver Newsletter" (various issues), World Bank.

Irrigated Agriculture

4.7 Clearly, irrigated agriculture will need to be the principal engine of agricultural growth, as it h been in the past. What are the prospects here? Area expansion is one production growth source. A shown in Table 4.3, past irrigation expansion was about 1.1 million hectares per annum in gross ter (including multiple cropping) or 0.8 million hectares per annum of new net land area brought und irrigation. Of this, expansion of surface irrigation contributed an average of slightly more than 0 million hectares per annum, with expansion of groundwater irrigation (predominantly priva tubewells) nevertheless dominating at nearly 0.6 million hectares per annum. Particularly rap expansion of groundwater irrigation occurred in the northwest, but groundwater irrigation is no spreading elsewhere, especially in the central Gangetic plain (e.g., Uttar Pradesh). The next sever decades are likely to see continued rapid expansion of groundwater irrigation in eastern and centr India, but a marked slowdown of groundwater development in the northwest and moderate expansio of groundwater irrigation in western and southern states of peninsular India, often dependent o surface irrigation development for groundwater recharge through percolation (Chapter II). Hence, the past rate of aggregate expansion of net irrigated area is to be maintained, by year 2000 to 2010, th share of new development for India as a whole between groundwater and surface water is likely t need to be nearer an about equal proportion of each. Eastern and central India irrigation developme is likely to be led by groundwater development for perhaps longer, but elsewhere, expansion o surface irrigation (including conjunctive use of groundwater) would primarily be required, relyin principally on creation of storage once the ongoing projects are completed. This change in relativ proportions is not what would be desirable from an economic viability perspective - Chapter II indicates that groundwater irrigation is much more economically attractive - but is likely to be essentia over time given the water resource situation.

Table 4.3 Past Rates of Development of New Irrigation (1970/71 to 1984/85)
(Million Hectares)

	1970/71	1984/85	Average Annual Increase (M ha)
Total Gross Irrigated Area	38.2	54.1	1.14
Total Net Irrigated Area	31.1	41.8	0.76
Of which (net):			
Canals	12.8	15.9	0.22
Wells	11.9	20.0	0.58
Other	6.4	5.9	-

Data Source: MOA, Directorate of Economics & Statistics.

4.8 There are obvious questions concerning what can be and should be the rate of expansion of irrigation in the future. If performance of irrigation management declines or remains poor, a minimal position might be best taken by government focussed on fostering expansion of private groundwater irrigation and a modest program for expansion of surface irrigation concentrated in dry areas and poverty areas (providing that management performance in these areas can be improved to assure reasonable impact from such investment). Under improved sector management, a more aggressive program might be undertaken. Under any chosen area expansion program, expansion of irrigation needs to be focussed on the opportunities with highest economic viability, fastest payback and lowest associated public expenditure cost. The options discussed in Volume I para 3.2 need to be the priorities: private groundwater development, completion of viable ongoing projects, development of

micronetworks, drainage and selective flood control and land rehabilitation. Large scope for area expansion is available through these actions for at least a decade.

4.9 The desirable rate of expansion is dependent both on the performance and viability that is feasible for future irrigation development and on the practical considerations of the availability of public funds and the rate at which projects can be successfully prepared and implemented. Relative to these practical considerations, expansion of surface irrigation would be under strain if it was greatly accelerated, though focus on project completions and micronetwork development might enable more rapid development within current implementation capabilities. For discussing potential future growth impact, an upper limit assumption for future surface irrigation expansion of up to 0.6 million net hectares per annum might be feasible but would greatly stretch implementation capabilities given current management performance and past development rates (0.2 million net hectares per annum). For private groundwater irrigation, past aggregate growth of 0.6 million net hectares might accelerate through the medium term to 0.8 million hectares. The reasonably feasible range for future expansion of irrigation from both sources is thus likely to be between 0.6 million net hectares (low expansion scenario based primarily on groundwater) to 1.4 million hectares. The latter outside range is very unlikely and not desirable unless excellent management can ensure good construction, maintenance and water management.

4.10 The other growth impact from irrigation is through productivity improvement. In the past, the combined impact of yield improvements and diversification on existing irrigated lands may have resulted in a 1 to 1.5% per annum increase in the value of output per hectare per crop for Indian irrigation as a whole. Its future feasibility can be considered in terms of foodgrain equivalents (yield feasibility is more easily discussed) as follows. If the national average for irrigated foodgrains in 1984/85 was just under 2t/ha (Chapter I), 1.5% per annum output growth would imply an average yield (foodgrain equivalent) of 2.5t/ha by the year 2000. State level data (Table 1.5) indicates that in 1983/84 a state average irrigated yield of 2.5t/ha was surpassed only in Punjab (3t/ha), though Haryana, Gujarat and Karnataka were nearly at this level. Further, on a number of commands in southern India, higher yields are obtained and field assessments in eastern India reveal that individual farmers can substantially surpass 2.5t/ha. From these perspectives, an output growth per hectare from existing irrigated land of 1.5% per annum is attainable but would not be easy as a national average.

4.11 The second element of productivity growth is cropping intensity (Table 1.3 for past changes). Irrigated cropping intensity increased by a little under one percentage point per annum in the past. This was greatly exceeded in Punjab and Haryana in the 1960s and 1970s, as a result primarily of the expansion of tubewell irrigation. Attainment of a 1.0% increase per annum in the future as a national average is possible but would require substantial growth of groundwater irrigation (including conjunctive groundwater irrigation in association with surface irrigation) and improved water management on surface irrigation commands.

B. Agricultural Growth Under Different Assumptions

4.12 Table 4.4 summarizes the estimated agricultural growth outcome of alternative sets o assumptions for development of rainfed and irrigated agriculture.[6] Scenario A may approximatel represent past growth influences; irrigated area expanding by 0.8 million net hectares per annum irrigated cropping intensity and productivity per crop (yield and diversification impact combined) b 0.8% and 1.3% per annum respectively, and rainfed productivity increasing by about 1.0% per ha pe annum. A 2.5% agricultural growth (the past rate of growth) results. If the rate of productivit growth of irrigated agriculture declines and the expansion rate of irrigated area also declines, a lowe agricultural growth can be expected (Scenario B). The other scenarios lead to several observations o relevance to future development strategy.

4.13 Firstly, excellent rainfed agricultural performance (even if attainable) would not in itself assur a high growth path for Indian agriculture. Scenario C assumes productivity growth of rainfe agriculture at 2.0% per annum, twice its past rate, while irrigated area is assumed to expand at its pas rate and irrigation's rate of productivity growth to decline slightly. Agricultural growth would improv slightly (to 2.6% per annum) but this rate of aggregate yield growth on rainfed lands is unlikely at leas in this decade (para 4.6).

4.14 Secondly, an attempt to achieve rapid expansion of irrigated area would also not be sufficien by itself for good agricultural growth. Scenario D assumes the same growth in productivity of rainfe agriculture as in the past, a slight improvement in the productivity growth of irrigated agriculture and a very large increase in the rate of expansion of irrigated area; a doubling from 0.8 million net hectares per annum in the past to 1.6 million net hectares per annum. Agricultural growth would be somewhat improved (to about 3.2% per annum), but this rate of expansion of irrigated area is unrealistic and probably undesirable unless accompanied by much improved performance of irrigation (para 4.9).

4.15 These findings lead to a third observation illustrated in Scenarios E and F. This is the strong impact of irrigation's productivity on agricultural growth. In Scenario E where irrigated yield growth is increased, past agricultural growth is shown maintained even if expansion of irrigated area is reduced to half its past rate. In Scenario F, which maintains the past rate of expansion of irrigation but the same high irrigation productivity assumptions as Scenario E, an agricultural growth rate nearly equal to Scenario D (very high area expansion) is possible.

4.16 Finally, Scenario G illustrates one set of assumptions that would achieve high agricultural growth (4.0% per annum). It would likely need (as illustrated here) high productivity growth from irrigated agriculture, significant acceleration of area expansion of irrigation and improved yield growth from rainfed agriculture.

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6 These illustrative projections are based on the estimated areas and outputs of rainfed and irrigated agriculture in 1984/85 estimated from Ministry of Agriculture, Directorate of Economics and Statistics data. The simplifying but reasonable assumption is made that future expansion of net irrigated area involves no increase in net cultivated area, but substitution of irrigated land in place of formerly rainfed land (due to the land ceiling in total net cultivated area, para 4.2 and Table 4.1). Irrigation will, however, increase gross cropped area. Projected output as a result of the assumptions used is then expressed in terms of per annum output growth.

Table 4.4 Illustrative Sources of Agricultural Growth

SCENARIOS	A	B	C	D	E	F	G
DESCRIPTION	Continuation of past performance and irrigated area expansion trends.	Reduced rate of productivity improvement of irrigated agriculture; Maintaining rainfed agriculture performance growth.	Very high productivity of rainfed & low productivity of irrigated agriculture; irrigated area expanding at past development rate.	Moderate productivity of rainfed & irrigated agriculture; irrigated area expanding at very high rate.	Very high irrigation productivity; reduced expansion rate of irrigated area.	Improvements in irrigation productivity; maintaining past irrigated area expansion rate.	Very high productivity (rainfed and irrig.) and very high irrigation expansion.
1. PRODUCTIVITY							
1.1 Annual % Increase in value added/crop/ha[1]:							
Rainfed Agric.:	1.0	1.0	2.0	1.0	1.0	1.0	1.5
Irrig. Agric.:	1.3	1.0	0.75	1.5	2.0	2.0	2.0
1.2 Cropping intensity increases (% per annum, irrigated crops):	0.8	0.5	1.0	1.0	1.0	1.0	1.25
2. IRRIGATION EXPANSION (Annual expansion of net irrigated area in million ha):	0.8	0.6	0.8	1.6	0.45	0.8	1.3
GROWTH IN AGRICULTURAL OUTPUT (% per annum):	2.5	2.0	2.55	3.2	2.5	3.1	4.0

[1] Combined Impact of Increases in Yields and Diversification to Higher Value Crops

4.17 In summary, the following implications may be highlighted:

(a) Improved performance of rainfed agriculture will be a factor in future agricultur growth and is particularly important from a welfare perspective as the bulk of Indian n farmed area is and will remain under rainfed conditions. However, improved rainfe yields, even under optimistic assumptions, cannot maintain or accelerate agricultur growth without improved performance of irrigation. Irrigation will be the princip determinant of future agricultural growth.

(b) Continued expansion of irrigated area will be a key factor for future agricultura growth. However, within the feasible and desirable rate of expansion of irrigated area expansion of net area has less growth impact than increases in the productivity o existing irrigation.

(c) Improving the productivity of irrigation (yields and cropping intensity) is thus o particularly critical importance. Expansion of groundwater irrigation, in conjunctiv use with surface irrigation or (as feasible, e.g., in large parts of eastern and centra India) by itself, will have large impact. For surface commands, improved wate management will be particularly important supplemented by continued improvement i extension, research and other services (Volume I, Chapter IV).

(d) Achieving agricultural growth in excess of its past rate is achievable but will necessarily require much improved performance of irrigated agriculture. As discussed in Volume I, this will require rigorous tackling of an array of issues inhibiting current performance levels and will also need addressment of construction quality, maintenance and environmental issues threatening both the performance and sustainability of irrigation.

Chapter V: Financing Irrigation Operations

A. Financial Situation of the Irrigation Sector

Historical Development and Current Situation

5.1 Until the early 1950s, irrigation development in India was financially profitable. With the exception of some "unproductive irrigation works" undertaken as drought relief measures, irrigation was classified as a "commercial undertaking". Revenues from water charges levied on beneficiary farmers were larger than Government expenditures on operations and maintenance and imputed interest on the initial investments. Over time this situation has eroded. In 1945 the net profit of the irrigation sector in pre-partition India was some Rs 80 million. Even after partition, which resulted in the transfer of a substantial part of the more profitable irrigation schemes to Pakistan, the sector still made a profit of Rs 10 million in 1947. By 1967-68 a net annual loss of Rs 580 million was incurred. The difference between current revenues from major and medium irrigation projects and non-Plan expenditures on these projects reached Rs 23.5 billion in 1988-89 (RBI, 1989). Further, these net losses are expressed on current expenditures only, without inclusion of allowances for capital recovery. Rural electricity subsidies, primarily for pumping water from tubewells, accounted for another Rs 14.6 billion (1986/87, current prices). Subsidies to irrigation grew by 10% per annum in the 1980s while rural electricity subsidies grew by 15% per annum. Irrigation and electricity subsidies now represent the bulk of rural subsidies in India; in 1986/87 irrigation was 37% and electricity 27% of total rural subsidies.[1]

5.2 The evolution during the 1980s of revenues and expenditures on major and medium irrigation projects in India are summarized in Table 5.1 (1980-81 and 1988-89). Over the past decade, revenues from collection of water charges have increased modestly (by 29%) in real terms due primarily to the expansion of canal irrigated area. By contrast, non-Plan expenditures (expenditures on operations, maintenance and administration) increased during the decade by 280% in real terms and are now 14 times greater than revenues. Plan outlays on irrigation saw some expansion in real terms (by 31%) though less than the expansion of total Plan outlays which increased by 42%. The steep rise in non-Plan expenditures has been the major change and has caused a significant shift in the composition of total expenditures on irrigation. Thus, whereas at the beginning of the decade, most expenditures on major and medium irrigation went on investments (78%), by 1988-89 only 55% of irrigation expenses came under the Plan (investment) budget, the rest being on recurrent (non-Plan) expenditures. Details of non-Plan and Plan expenditures by state are at Annexes 5.1 to 5.4.

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[1] Source: "Agriculture Challenges and Opportunities" (India 1991 Country Economic Memorandum, Agriculture Operations Division, India Department, World Bank).

Table 5.1 Revenues From And Expenditures On Major & Medium Irrigation Projects
(Rs. Million at 1980-81 Prices)

	1980-81	1988-89
Revenues (Current Account)	874	1,125 (+29%) a/
Non-Plan Expenditures	3,930	15,000 (+280%) a/
Plan Outlays (Capital Disbursements)	13,954	18,260 (+ 31%) a/
Revenues as % of Non-Plan Expenditures	22%	7.5%
Plan Outlays as % of Total Expenditures (Plan and Non-Plan)	78%	55%

Source: Reserve Bank of India Bulletins
a/ Percent increase of 1988/89 over 1980/81.

5.3 The steep decline in the net financial situation of the irrigation sector is due to the combined impact of a decline in real terms in per hectare revenues from water charges and a huge increase in recurrent expenditures. A further problem has been the rise in per hectare costs for new investments.[2]

Revenues from Water Charges

5.4 Water charges form the basis for collection of direct revenues from the irrigation sector. These are levied annually for surface schemes on a per hectare-crop basis with different rates depending on crop and season; generally higher rates for more water consuming crops and in seasons when irrigation water is more scarce. For electric tubewells, an annual fixed charge per unit of horsepower is applied. Water charges vary considerably between states as shown for rice and wheat surface irrigation charges in Table 5.2. An important further factor influencing the actual revenues collected is the collection rate achieved which is quite variable between states and also varies between years. The slow growth, despite expansion in irrigated area, in revenues from water charges is due to two factors. First, rates have been very infrequently revised resulting in substantial erosion over time in their real values. Water charges have not been changed since the mid 1970s in Punjab, Haryana, West Bengal and Tamil Nadu, and not since the mid 1980s in other states (Table 5.2). Second, while aggregate data is not available, individual state and project level data indicates that collection rates have also declined in a number of states, especially in the last several years. As a result, revenues from water charges are now well below recurrent expenditures on operations and maintenance for irrigation and are a very minor element in overall

2 "Water pricing and Cost Recovery in the Irrigation Sector", R. Bhatia, Irrigation Sector Review Background Paper (Draft, 1990).

state revenues. Revenues from water charges average 0.4% of total state revenues, while recurrent expenditures on major and medium irrigation projects average about 6% of state non-Plan expenditures. Further, in some states the costs of collection may now exceed the revenues collected.[3]

Table 5.2 Water Rates for Rice and Wheat in Selected States

State	Water Rates (Rs/ha)		Water Rates Expressed in Terms of Equivalent Value of Crop (Kgs/Ha, January 1986 crop prices)		Year in Which Water Rates were Last Revised
	Rice	Wheat	Rice	Wheat	
Punjab	48.2	24.1	32.8	14.9	1974
Haryana	74.1	61.8	50.8	37.2	1975
Bihar	89.4	51.1	55.9	30.3	1983
Uttar Pradesh	143.3	143.3	116.5	93.1	1983
Orissa	39.5	32.1	N.A.	N.A.	1981
West Bengal	37.1	49.4	21.3	32.3	1977
Madhya Pradesh	59.3	61.8	43.6	35.7	1984
Andhra Pradesh	148.3	148.3	107.4	N.A.	1986
Karnataka	86.5	54.4	53.4	22.9	1985
Tamil Nadu	37.1	N.A.	13.9	N.A.	1962

Data Sources: Rates for surface water in India, January 1988, Central Water Commission and Agricultural Situation in India/Farm Harvest Prices of Principal Crops in India (1982-83 to 1985-86).

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[3] Water charge collection procedures vary from state to state but usually involve a special wing of the Irrigation Department and a fairly cumbersome and expensive bureaucracy. Field staff involved in Bihar go from door to door for collection. Due to the heavy costs involved and the poor recovery rate, typically less than 30% of the assessed rates, such collection costs may exceed the value of revenues collected. This was found to be the case in 1982-83 when staff costs for the revenue establishment were estimated to be Rs 60 million while collection amounted to only Rs 53 million (Bhatia, 1989). Another study found that collection costs in Bihar and Maharashtra ranged from 46-84 percent of the total amount collected (during 1977-78 to 1983-84, Prasad and Rao 1985). In Maharashtra, Irrigation Department officials prepare lists of farmers and associated areas by crop to form the basis for charging, but collection is done by the revenue wing of the civil administration. This has the advantage of partially separating irrigation officials from the unpopular function of collection, but collection rates there are also not high, about 70 percent of assessed charges.

Among the best systems found in India is that used in Punjab. This starts with the considerable practical advantage that crop statistics are well known and recorded and change infrequently. The Patwari (village revenue official) is responsible for collection and is allowed to keep 3 % of revenues as an incentive. While the assessed rates for water charges in Punjab are quite low relative to other states (and have not been changed since 1974), the recovery percentage is high at nearly 100 percent. In most states there is a need to rethink collection procedures. An attractive possibility would be using farmer organizations or village panchayats for field level bookkeeping and collection,which, as in Punjab, could keep an agreed proportion of revenues as an incentive (Volume I, para 3.18e).

The Rise in Non-Plan Expenditures

5.5 The steep rise in non-Plan expenditures on irrigation has primarily been due to escalation of expenditures on establishment (staff costs). While data on non-Plan expenditures is not systematically disaggregated into its component parts in standard state data reporting, the situation present to a greater or lesser extent in most states is illustrated in Table 5.3 based on Annexes 5.5 to 5.7.[4] An extreme situation is found in Bihar where establishment costs increased by 148% in only four years (1980-81 to 1984-85) while expenditures on works related to maintenance declined slightly in the same period. The growth of establishment costs in Bihar was influenced both by a doubling of the costs of the revenues establishment (personnel involved with collection of water charges) and by a 2.6 fold increase in the costs for operations and maintenance staff. A similar picture emerges from analysis of data at the level of individual commands. On Bihar's Sone and Kosi commands, expenditures on works showed little change between 1980-81 and 1984-85 while establishment costs increased by 102% and 240% respectively.[5] Project level data for Gujarat reveals a 61% to 169% increase in establishment costs on four commands during periods spanning 3 to 4 years in the 1980s, while works expenditures decreased on two commands. In Maharashtra, while expenditures on works increased by 137% from 1980-81 to 1984-85, nearly half of the increase in Maharashtra operations and maintenance expenditures (113% in 4 years) is accounted for by an increase in establishment expenditures.

Table 5.3 Changes in Operation and Maintenance Expenditures in Selected States and Projects

		Percent Increase in Establishment Costs1/	Percent Increase (+) Decrease (-) in Works Costs	Per cent Increase in Total Expenditures
A.	State Level Data			
	Bihar			
	(1984-85 over 1980-81)	+ 148	- 4	+ 62
	Maharashtra	+ 94	+ 137	+ 113
	(1983-84 over 1979-80)			
B.	Project Level Data			
	Bihar			
	(1984-85 over 1980-81)			
	Sone Command	+ 102	+ 5	+ 66
	Kosi Command	+ 240	- 11	+ 60
	Gujarat			
	(1985-86 over 1981-83)			
	Dantiwada Command	+ 169	+ 14	+ 72
	Kakarpar Command	+ 111	- 5	+ 38
	Mahi Command	+ 61	+ 24	+ 40
	Shetrunji Command	+ 80	- 5	+ 16

1/ In Bihar, this includes the costs of the staff involved with collection of water charges.
Source: Adapted from R. Bhatia, Pawar and H. Patel. Details in Annexes 5.5 to 5.7.

4 Data has necessarily been confined to that available from studies. It is recommended that all states do a similar diagnostic (Volume I, para 3.12a).

5 As shown in Annex 5.6, increases in both operational establishment costs and revenue collection establishment costs were involved; up 732% and 125% respectively in the case of the Kosi command.

5.6 Little productive impact has been achieved as a result of the expansion of non-Plan expenditures on irrigation. Urgent improvement in operations and maintenance is still needed in most states (Volume I, Chapter IV). But expenditure growth has probably contributed little to this objective being absorbed instead in financing growth of staff numbers and resultant wage bills. Field observations suggest that all states in India suffer in varying degrees from inadequate maintenance expenditures. Thus, in Punjab, where maintenance has been comparatively good, an average of 85% of the non-Plan irrigation budget between 1986-87 and 1989-90 was spent on salaries and work charge establishment, and, in the same period, identifiable expenditures on maintenance decreased by 40%. Government concern with maintenance needs across India is reflected in such commentaries as "maintenance of existing irrigation systems is not getting the attention of states as required" (Public Accounts Committee 1983) and "One of the main reasons for under utilization of irrigation potential was that the maintenance of irrigation and drainage systems was neglected" (GOI, 1990).

Increasing Investment Costs

5.7 Another concern has been the rise in the costs of new irrigation development over time. A comparison of investment costs per hectare under the Fifth (1974-79) and Sixth (1980-85) Plans found that investment cost per hectare had increased in real terms by 57% (average for 14 states, V. Ravishankar and New Concept Consultancy Service, 1989). Further increases in real costs are likely to have occurred during the Seventh Plan (1985-90) if experience with cost-overruns on World Bank assisted projects (Chapter III) is indicative of the situation elsewhere. The reasons behind rising investment costs need further examination. A likely outcome is that cost increases are substantially due to implementation inefficiencies because of lax contracting and supervision practices in the presence of inadequate systems for monitoring, cost analysis and control of expenditures (Volume I, para 3.10).

B. Improving Sector Financing and Funding of Maintenance

5.8 The situation described above has serious repercussions on both the physical and financial sustainability of future irrigation development in India. Funding of sector priorities such as maintenance and improved operations is inadequate in most states and construction is suffering from both increased costs and poor construction quality (Volume I, para 4.30). The combined impact of poor construction quality and poor maintenance will create increased needs for funding of rehabilitation. Meanwhile, construction (and rehabilitation) costs per hectare are mounting. While recurrent expenditures have increased enormously, funding has seldom been used for assuring physical sustainability, i.e., for effective maintenance, being instead absorbed by staff costs. Continuation of the trends of the past decade found in most states would result in an increasingly heavy financial burden, limiting possibilities for funding of new investments, and also resulting in deterioration of existing infrastructure and progressive decline in the effectively irrigated area.

5.9 Provision of extra money to the sector is likely to be very inefficient unless basic deficiencies in sector monitoring and control of expenditures are tackled. At present, the irrigation management apparatus is poorly equipped and oriented to deal with these issues. Basic data relevant to physical monitoring and cost accounting is seldom collected, financial analysis

capabilities are well short of those found in private business, and policy managers have seldom focussed on the efficiency of usage of funds and analysis of trends. Addressing these deficiencies is an urgent priority.

5.10 Substantial improvements to this situation are possible, but will depend importantly on the willingness and ability of the states to effect change, and corresponding monitoring and financial incentives at state and central Government levels. Detailed recommendations are provided in Volume I, paras 3.10 to 3.12. At the level of each state they include quick diagnostic reviews of the key issues involved followed by preparation and implementation of action programs to assure adequate funding of field maintenance activities, control of staff numbers, improvement in cost accounting and financial management and control of construction quality and costs. For maintenance, annual Maintenance Plans are recommended following agreed formats and careful clearance by state authorities. Annual Maintenance Budgets would be based on these plans and must receive priority state financing. Financial management and improvements in financial performance would be monitored and steered by Irrigation and Finance Departments through preparation of Annual Irrigation Department Financial Reports following an analytical format designed to focus on issues of concern and guide improvements. Central Government would review the Annual Maintenance Plans and Budgets and the Annual Financial Reports as part of the monitoring and decision making process in the disbursement of central Plan and non-Plan funds (Volume I, paras 3.19 and 3.20). A sustained process of improvement should be insisted upon by both state and central government authorities.

5.11 Successful implementation of these reforms should be a major concern for both state governments and GOI. There is little point in funding new investments in any state if existing investments are deteriorating and measures are not being taken to improve the efficiency of expenditures and curb recurrent expenditure growth. For GOI, adequate handling of the above, including observable progress from field observations, should be made a condition for allocation of central government funds (Volume I, para 3.20). For those states where difficulties are being encountered in meeting recurrent expenditure needs, despite implementation of improvements in efficiency, consideration could be given to use of Plan funds for maintenance on the basis of an adequately prepared state maintenance budget and implementation program.

C. Cost Recovery Policy

5.12 The other cause of the irrigation sector's sharply deteriorating financial performance has been cost recovery. The low level and poor collection of water charges has been a persistent and intractable issue affecting nearly all irrigation projects in India. Technical and administrative reasons behind low cost recovery include the poor service provided on many irrigation commands (resulting in low income improvements and leading farmers to consider that they have no obligation to pay) and poor assessment and collection procedures. The politicization of water charges, with politicians frequently promising not to increase rates or forgiveness of non-payment, has been a major factor behind both the minimal changes over time in water charges and in the low collection percentages even of assessed rates. Additionally, there has been some debate in India and in the academic literature on the principles and objectives to be employed for cost recovery. This section will begin by reviewing the main arguments in the debate, and will subsequently examine the impact of water and electricity charges on farmers as background to the discussion and recommendations in Volume I (paras 3.13 to 3.18).

Principles of Water Charges and their Application in India

5.13 The academic literature generally cites three principal objectives to be considered in the establishment of water pricing: efficiency, equity and financial. Central Government policy in India has tended to share these objectives, but has put greatest emphasis on financial considerations. The National Water Policy in 1987 laid down the following directives on water rates and maintenance; "water rates should be such as to convey the scarcity value of the resources to the users and to foster the motivation for economy in water use. They should be adequate to cover the annual maintenance and operation charges and a part of the fixed costs. Efforts should be made to reach this ideal over a period, while ensuring the assured and timely supplies of irrigation water." Despite these concerns, little impact has been achieved at state levels where local politics favoring subsidies to farmers have resulted in the substantial erosion of sector financial viability noted above. Similarly, efficiency and equity objectives have had little practical policy impact.

5.14 Efficiency Objectives. The efficiency consideration holds that pricing of water used by farmers can serve to help optimize the quantity of water applied by farmers so that water usage is economically efficient. This classical economic reasoning is generally recognized to have distinct practical limitations in most irrigation situations. It would assume that farmers have control over the quantity of water that they receive which does not hold at all in supply based systems such as warabandi in northwest India, and in the field to field irrigation systems in eastern India and in most delta schemes. In demand based systems it would imply that irrigation management has sufficient control over water supply and monitoring at the level of individual farmers to make this feasible, a situation not yet found in India and seldom found elsewhere in the world. Other problems include that the value of water varies, partly unpredictably, throughout the year in response to variable rainfall. Allocation of water through equating the price or marginal cost of water with its marginal value product would involve continually varying the price of water. Also, marginal cost pricing would require that other objectives such as equity and fiscal considerations would need to be treated as secondary in importance. Finally, pareto-optimal allocation of water through marginal cost pricing requires that offsetting distortions are not present for other prices affecting farmer decisions.

5.15 Given these problems, exclusive reliance on efficiency pricing of irrigation water as an allocative mechanism is worldwide very seldom used and is similarly unlikely to be practical in its pure form in India. Some proxies for the objectives of pricing as a mitigating mechanism against wastage are, however, found in India or have practical possibilities for application. In ground-water exploitation the most efficient users of water are those farmers with diesel pumps that pay for fuel in proportion to water extraction. By contrast, owners of electric pumps pay a flat annual fee based on horsepower of their pumps and little variable cost is associated with varying their extraction rates. This is one reason why electricity subsidies are getting so out of hand and rural power supply is substantially lagging behind demand. It also encourages indiscriminate and environmentally damaging over-exploitation of groundwater. On surface schemes, water pricing nearly throughout India is charged on a per hectare-crop basis at varying rates depending on crop and crop season; higher rates for more water consuming crops and in the rabi and summer seasons when water is scarcer. This has been assessed to have little impact on the farmers' usage of water for a particular crop - he will use as much water as he can get and thinks he can usefully use - the real influence on usage being the physical water allocation system and the degree of rationing that this imposes on the farmer . Different rates per crop may have an impact on the farmer's decision on choice of crop. Such influence is, however, minor as water rates are usually small relative to irrigation benefits (para 5.21). One possibility that offers potential practical scope for further development in India is volumetric pricing of water to groups of farmers as practiced in some Pani Panchayats in Gujarat and Maharashtra and to be piloted in Majalgaon command under the

Maharashtra Composite Irrigation III Project (Credit 1621). Thus, if Indian irrigation over time becomes more sophisticated in terms of both water controlling structures and management capabilities, the applicability of efficiency pricing considerations will become more relevant.

5.16 Equity Objectives. Equity arguments for water charges hold that as irrigation confers substantial benefits on farmer incomes, these same farmers should pay back part of the substantial "economic rent " that they receive from irrigation. A second aspect of the equity objective is to apply water charges in a manner that will be progressive in impact, with higher rates to farmers that can afford to pay more. Achieving the first equity principle is generally possible and consistent with the financial objectives discussed below. As discussed by Repetto[6], economic rents enjoyed by irrigated farmers are usually much larger than even full cost coverage water charges would amount to. Hence, achievement of cost recovery through application of water charges would also serve to tax the economic rents of beneficiaries, and in general runs little risk of exceeding such economic rents.

5.17 Achieving the second equity objective is much more complicated as it would require individual assessment of the abilities of each farmer to pay, inviting both bureaucratic growth and potential for abuses. This objective is partly applied in India, with exemptions provided in many states for marginal farmers and with seasonal exemptions to farmers with poor yields. Given the administrative problems and expenses involved, and the quite marginal impact of even increased water charges on farmer welfare in most circumstances (para 5.21), such provisions are not recommended. An exception could be where water pricing decisions are applied internal to a water user association. The WUA, while maintaining the global level of its provisions to the authorities, could have the freedom to make such decisions based on its better understanding of the circumstances of individual farmers.

5.18 Financial Objectives. In view of the fiscal importance of addressing the financial sustainability of irrigation development, and the practical limitations in applying the first two water charges principles, this objective appears the most important. This objective is usually viewed from the perspective of direct revenues; i.e., from water or electricity charges. A broader perspective has sometimes been proposed by state governments and academics. The argumentation is that revenues stemming from the irrigation sector include not only the direct revenues from water charges but also revenues from direct taxation of irrigated farmers and indirect taxes arising from expenditures incurred as a consequence of higher incomes from irrigation. Additional revenues may also be available through charges such as betterment levies, employment cess, education cess and mandi (market yard) charges resulting from sale of additional marketed surplus. In Bihar, gross revenues from irrigation charges in 1984-85 amounted to 126 million Rs while the additional incidence of indirect taxes on irrigated farmers has been estimated at 622 million Rs (Bhatia, 1989, refer Annex 5.8). In Maharashtra, the Employment Guarantee Scheme cess on irrigated agriculture and the education cess on irrigated area contributed Rs 160 M over a four year period (1980-81 to 1983-84) which formed 22 percent of the total receipts from irrigation (Pawar 1985). States with greater taxable agricultural wealth and taxable agricultural surplus than Bihar are likely to have a larger proportion of irrigation sector based revenues stemming from non-water charge sources. Thus, in Punjab, water charges have been estimated to amount to only 10 % of indirect taxes from irrigated farmers.

5.19 The perspective does, however, have its limits. Such revenues must also pay for services such as education, other infrastructure and other government services. For many of these services,

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[6] R. Repetto, "Skimming the Water: Rent Seeking and the Performance of Public Irrigation Systems", World Resources Institute, 1986.

cost recovery is less feasible as the identification of beneficiaries is more difficult and for many services, while they may be important, they are not directly productive in an immediately identifiable way (administration, health, etc.). The critical financial situation prevalent in most states seldom provides the luxury of forgoing revenues from productive services that directly increase the income of beneficiaries. Further, relying on indirect revenues is counter to equity concerns. Under good irrigation, farmers gain substantial economic rent from the irrigation service. Water and electricity charges provide a direct way of charging beneficiaries for an irrigation service which directly benefits them, whereas indirect taxes also tax non-beneficiaries. While it has been argued that agricultural market charges are a proxy for water charges in that they are levied on farmers with surplus production who may well have irrigated holdings, the relationship to the irrigation services is far from universal; surplus producing rainfed farmers are also taxed which is inequitable. Farmers receiving irrigation get a service which provides them with private benefits. It is, thus, reasonable to expect that the service should be paid for. Where a state is short of money, every opportunity must be taken to generate revenues, and water and electricity charges each represent very significant opportunities. The total water and electricity subsidies involved - two-thirds of rural subsidies - grew by 10% (irrigation) and 15% (rural electricity) per annum in the 1980s and are an increasingly heavy strain on state budgets, eating into the affordability of productive investments.

5.20 For electricity, the issue is more urgent as fixed rate subsisized electricity is both seriously affecting the financial position of electricity Boards and causing indiscriminate and environmentally damaging over-exploitation of groundwater. For irrigation, acceptance of irrigation subsidies would presume that serious state financial constraints are not present. In no state is this the case. Water charges will also be the eventual financial basis for independently managed surface irrigation schemes (Volume I, paras 5.22 to 5.25). Further, as discussed below, there is no reason why farmers cannot afford in most situations to pay for the irrigation service that they receive.

Impact of Water Charges on Farmers

5.21 Much has been made by farmer pressure groups of the difficulties farmers have in paying water charges. Analysis does not back this up except in special circumstances. While water charge rates are quite variable by state (Table 5.2), they are generally a small percentage of returns from irrigation. Relative to gross returns they are usually less than 2%, and relative to net additional returns from irrigation (a proxy for the "economic rent") are usually less than 4%. Typical values for rice are between Rs 35 and 75 per hectare representing only some 15 to 50 kgs of paddy or generally less than 3% of crop yields. Table 5.4 summarizes analyses from six states.

Table 5.4: Irrigation Charges, Gross Return & Net Return for Canal Irrigation

State	Crop	Irrigation Charges (Rs/Ha)	Irrigation Charges as % to Gross Return	Irrigation Charges as % to Net Return	Irrigation Charges as % to Net Add'l Return from Irrigation
U.P.	Sugarcane	349	4.6	12.2	N.A.
Bihar	Paddy*	75	1.6	2.3	4.3
	Wheat*	79	1.2	1.5	4.0
	Paddy**	40	0.9	1.2	2.9
	Wheat**	32	0.8	1.2	2.9
	Paddy***	348	6.3	21.3	-
Orissa	Paddy	53	1.0	4.5	N.A.
Gujarat	Paddy	110	1.1	1.4	1.5
	Wheat	110	1.9	2.4	2.6
	Bajra	40	0.8	1.0	1.2
	Groundnut	200	1.9	2.7	3.6
	Cotton	55	0.4	0.5	0.6
Maharashtra	Wheat	100	3.6	11.4	-
	Paddy	105	4.0	11.9	-
	Sugarcane	740	5.3	10.7	-
	Hybrid Jowar	77	1.9	4.2	11.5
	Hybrid Bajra	108	5.1	20.3	29.6
Tamil Nadu	Paddy	37			3.7
	Sugarcane	50			1.5
	Cotton	50			1.7
	Ragi	20			3.7

*Estimate I **Estimate II ***Estimate III

Sources: Bhatia (1989), Pawar (1985), Patil et al (1980), Brahmabhatt (1988)

5.22 The exception to these typical situations would be where farm yields are low so that water charges are proportionately harder to bear. This is illustrated in Table 5.5 for Bihar farmers. Under low yields - assumed at 1.2 tons per hectare for wheat and 0.8 tons for paddy - water charges reach 7 % of net returns for wheat and 28 % for paddy.[7] But provision is made in most states for exemptions to farmers in case of such difficulties, a safety net frequently misused by farmers and local level political representatives.

[7] The yield assumed in the "minimum case" in Table 5.5 is taken for illustration, but would be very poor even under rainfed conditions.

Table 5.5 Net Return, Gross Return and Irrigation Charges for Wheat and Paddy Crops in Bihar
(Rs./Ha)

Particulars	Wheat			Rice		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Yield (Kg/Ha)	1182	2897	4123	808	2154	3182
Gross Return (GR)	2365	6612	8246	1212	4616	5409
Net Return (NR)	1430	5325	7936	269	3284	3494
Irrigation Charges	101	79	88	75	75	73
Irrigation Charges (IC) as % to GR	4.3	1.2	1.1	6.2	1.6	1.4
IC as % to NR	7.1	1.5	1.1	27.9	2.3	2.1
If Irrigation Charges are Doubled:						
IC as % to GR	8.6	2.4	2.2	12.4	3.2	2.8
IC as % to NR	14.2	3.0	2.2	55.8	4.6	4.2

Source: R. Bhatia (1989)

5.23 Table 5.6 illustrates the impact of adjusted water charges in Haryana, Bihar, Gujarat and Maharashtra under different assumptions. The assumption on full recovery of O&M costs is based on an assumed cost of Rs. 160/ha as recommended by the Seventh Plan Working Group on Major & Medium Irrigation Projects. In none of the states would irrigation charges have to be raised to be more than 4.5% of net additional benefits from irrigation. The principle of coverage of O&M costs by irrigation is thus affordable for farmers providing that the irrigation service is having at least modest impact on yields.

5.24 Inclusion of Capital Costs. Larger consequences on farmers emerge if irrigation charges are adjusted to cover amortization of capital costs as well. Even under low cost of investment assumptions, Table 5.6 shows that 100% coverage of capital investment costs would result in water charges amounting to about 25% of gross returns from irrigation in Haryana, 18% in Gujarat and Maharashtra, and 38% in Bihar. Expressed as a percentage of additional farmer benefits from irrigation, water charges would represent 50% and 77% respectively in Haryana and Bihar. This still leaves the farmer with an improved situation compared with rainfed farming, but susceptibility to yield variation risks would be high. Partial coverage of capital costs does, however, look to be reasonably supportable by the farmer; for instance a 25% coverage of capital costs would represent only 8 and 11% respectively of gross returns in Haryana and Bihar under low capital costs assumptions. The ratios are higher, 10% and 18% respectively, if higher investment costs are assumed.

Table 5.6 Irrigation Charges and Returns from Irrigation Under Alternative Cost Recovery Assumptions

States/Cost Recovery Assumptions	Irrigation Charges as % to Additional Benefit from Irrigation		Irrigation Charges as % to Gross Return	
	Low Capital Cost	High Capital Cost	Low Capital Cost	High Capital Cost
HARYANA				
O&M Cost Only	4.5	4.5	2.2	2.2
O&M Cost + 100% Capital Charges	50.3	64.6	24.9	32.0
O&M Cost + 25% Capital Charges	16.0	19.6	7.9	9.7
BIHAR				
O&M Cost Only	4.1	4.1	2.0	2.0
O&M Cost + 100% Capital Charges	77.3	134.2	38.2	66.4
O&M Cost + 25% Capital Charges	22.4	36.6	11.1	18.1
GUJARAT				
O&M Cost Only	1.6	1.6	1.1	1.1
O&M Cost + 100% Capital Charges	25.5	68.4	18.8	50.4
O&M Cost + 25% Capital Charges	7.6	18.3	5.6	13.5
MAHARASHTRA				
O&M Cost Only	-	-	1.3	1.3
O&M Cost + 100% Capital Charges	-	-	17.8	33.8
O&M Cost + 25% Capital Charges	-	-	5.4	9.4

Note: Current irrigation charges for paddy plus wheat in Bihar and Haryana are Rs. 136 per ha, and Rs. 220 per ha in Gujarat. The irrigation charges for sugarcane in Maharashtra are Rs. 750 per ha.

Source: Adapted from Bhatia (1989), Pawar (1985) and Patel (1989).

Chapter VI Environmental and Resettlement Policy

6.1 The environmental and resettlement impacts of irrigation are widely debated but, due to lack of data and frequently one-sided perspectives, discussion has often been polarized. One point of view holds that any negative impact from irrigation on the environment and local populations is unacceptable. An opposing view is that negative environmental impact is small compared to the benefits of irrigation; a viewpoint that has often been the origin of inadequate attention to environmental and resettlement issues. A more balanced but much more responsive approach to environmental and resettlement issues is required.

6.2 The chapter begins with a brief overview of positive environmental impacts from irrigation (Section A). However, as the principal purpose is to take better account of detrimental effects, the bulk of the chapter will be focussed on reducing negative environmental impacts. First, for waterlogging and salinization (Section B), a proposed approach is outlined involving stepped up investment in development and maintenance of drainage, improved monitoring and research, and other supplementing measures such as improved water management and optimal use of groundwater extraction. Second, other environmental impacts , actual or potential, are reviewed: siltation, impact on river flows, risks from water borne diseases and chemical impurities in water, and destruction of flora and fauna (Section C). As most of these issues are still inadequately understood, further research and improved monitoring are required within an enabling institutional and funding environment. Third, the issues posed by land losses, population displacement and deforestation for reservoirs and canals are assessed; the dimensions of these problems and approaches to tackling them (Section D). Finally, improvements required for resettlement and rehabilitation policy and implementation are discussed (Section E).[1]

A. Positive Environmental Impacts

6.3 The most obvious effect of irrigation has been on the welfare of the Indian population, despite a three-fold increase in population size over the past five decades. Improvement in living standards has been possible for many rural dwellers in areas with widespread irrigation. This achievement, due mainly to increased yields from irrigated agriculture, has been largely driven by irrigation development (Chapter I). Similarly, susceptibility to droughts has been reduced in those parts of India where irrigation systems function effectively (para 1.12). The widespread famines of the past, which stimulated the administration in the 19th century to launch large-side investment in irrigation, are no longer a constant threat. This improvement in security was well demonstrated in the severe drought years of 1987 - 88, during which many irrigated areas were substantially unaffected, national food production dropped by less than 10%, and famine was averted (in a country with a population larger than Africa's). This was due to the stabilizing yield impact of irrigation coupled with distribution of domestic food stocks, primarily built up from surpluses coming out of irrigated regions, resulting in only moderate recourse to supplementary food imports.

6.4 An important impact of irrigation is that it reduces environmental problems on rainfed lands. First, irrigation creates biomass for cattle feed (one double cropped irrigated hectare of land can produce 8 tons per annum of straw) and fuel, reducing pressures from grazing especially where stall feeding is practiced, and providing additional potential for farm woodlots, which are increasing and are eventually likely to become commonplace. While the enormous pressures of population on the land are causing massive biomass and soil depletion of rainfed lands due to

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1 Additional analysis is contained in the following Irrigation Sector Review Background Papers : "Land Drainage and Reclamation" L.K. Smedema, (1990); "Environmental Issues Related to the Irrigation Sector" T. Blinkhorn and C. Rees, (1990); and, "Land Acquisition, Resettlement and Rehabilitation" W. Partridge and A. Salam, (1990).

overgrazing, firewood collection, cultivation of marginal soils and uncontrolled commercial timber operations, the problem would be considerably more acute without the reductions in such pressures due to the presence of irrigated lands. Other positive impacts include the benefits from provision of sources of village water supply for washing and groundwater resources for drinking water. Substantial hydroelectric power is also a product of many storage schemes, reducing the need to rely on thermal power systems, which can have greater adverse impact on the environment.

B. Waterlogging, Salinization and Drainage

6.5 The principal negative impact of irrigation on the agricultural environment is from constrained drainage due to irrigation and other infrastructure and from land waterlogging and salinization induced or aggravated by irrigation.[2] Waterlogging, in the form of temporary surface ponding or as high water tables affecting the root zone, reduces crop yields due to poor root aeration, and in extreme situations (flooding over an extended period) wipes out the crop. Both yields and the ability of farmers to plant their crops at optimal time periods are affected. As discussed in Chapter II, due to the pattern of heavy concentrated monsoon rains in India, a large aggregate area, both rainfed and irrigated and including areas with low annual rainfall, are affected by monsoon drainage problems. This problem can be exacerbated by irrigation. By its nature, irrigation moistens the soil, reducing the soil's water absorption capacity at the time of rains. Further, creation of structures such as canals and roads, when done without proper cross drainage provisions, has disrupted natural land drainage. Also, localized waterlogging problems have occurred from excessive seepage of water from canals.[3]

6.6 Another major problem that can be induced by surface irrigation is a rising water table. Under irrigation, recharge to groundwater will increase due to deep percolation. As a result, the water table will rise until a new equilibrium between groundwater recharge and discharge is reached. More often, this can be a positive environmental result of surface irrigation allowing access to groundwater from wells or permitting a higher groundwater extraction rate. Often, groundwater recharge is a deliberate design feature of a surface irrigation project. However, under

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2 "Land Drainage and Reclamation", L. K. Smedema, Irrigation Sector Review Background Paper, 1990.

3 Examples of blocking of natural drainage and waterlogging as a result of seepage from canals can be found in many commands in, for instance, the Indo-Gangetic plains. W. M. Barber, "The Rising Water Table and Development of Waterlogging in Northwestern India," 1985.

certain circumstances (for instance, some districts in Punjab, Haryana and Rajasthan), depending on the combined influences of the natural drainage properties of the land and soils, availability of supplemental drainage, rainfall and the irrigation regime, the water table may rise to the root zone diminishing yields. The soil may also become salinized when there is insufficient leaching by rainfall or irrigation and when the flux due to evaporation predominates.

Dimensions of the Waterlogging and Salinization Problem.

6.7 The total area subject to waterlogging in India was estimated by the National Commission on Agriculture of 1976 at 6 million hectares including both rainfed and irrigated areas. This is thought to be a substantial underestimate though precise data is lacking. Some 3 million hectares are estimated to be on irrigated lands, but only part of this waterlogging is induced by irrigation. Based on extrapolation of analysis from data on individual commands, it is estimated that, on average, irrigation induces waterlogging and/or salinization on some 3% of created command area (Smedema, 1990).

6.8 While in most parts of India, such problems on irrigated lands are localized to particular commands and most frequently to localized areas in such commands, a particularly serious problem is developing in parts of northwest India (large parts of Punjab and Haryana and parts of Rajasthan and Gujarat). Before irrigation development, water tables were generally at more than 25 meters depth. As illustrated in Annex 6.1, the rate of rise of the water table since irrigation began in the late 19th century, has in some areas been of the order of 25 to 30 cm/year. This had no impact until the water table reached the root zone or where the level of the water table allowed for capillary action salinization of the root zone from saline groundwater sources. The first signs of irrigation induced waterlogging and salinization were reported in the 1920s and the problem began to become widespread in certain districts of Punjab and Haryana from the 1950s. Yields are affected and some areas can no longer be cultivated. Over 0.6 million hectares in northwestern India are estimated to be affected by waterlogging. The "usar lands" problem (highly sodic salinized soils forming eventually a highly salinized hard pan preventing crop growth), found mainly in Uttar Pradesh, is also of concern. Only part of such usar lands have been caused by irrigation, but treatment and prevention of usar lands development depends on drainage.

Tackling Irrigation Induced Waterlogging and Salinity

6.9 The key to tackling most of the above problems is drainage. In the past, while the eventual need for drainage was recognized as early as the late 19th century, such investments were deferred on the grounds that they were not needed then and funding was best spent on new irrigation investments. Providing that drainage investments can be made in subsequent development phases (i.e. that it is physically possible to invest in an irrigation and drainage program in such a two stage manner and that irreversible ecological damage is not incurred by delaying drainage investments), this strategy makes good economic sense. However, the time appears to be now long overdue for tackling such deferred investments. This is increasingly recognized in Punjab and Haryana. In Punjab, a 1984 Government committee studied waterlogging problems, and studies have also been conducted at Ludhiana University and with UNDP support in Haryana. World Bank projects since the mid 1970's have put increasing emphasis on tackling the environmental problems induced by irrigation.[4] Major emphasis on drainage is, in particular, included in the Punjab Irrigation and

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4 For instance, in such projects as Haryana Irrigation II (Cr. 1319, 1983), Upper Ganga Irrigation Modernization Project in Uttar Pradesh (Cr. 1483, 1984), Madhya Pradesh Major Project (Cr. 1177, 1982), Maharashtra Composite Irrigation III Project (Cr. 1621, 1986), Upper Krishna Irrigation II (Cr. 2010/Ln. 3050, 1989), and Upper Krishna Irrigation II (Cr. 2010/Ln. 3050, 1989), project designs have incorporated drainage as well as irrigation investments.

Drainage Project Phase II (Cr. 3144-IN/Ln. 2076-IN, FY90), and in the Narmada Water Delivery and Drainage Project (Cr. 1553, FY85). The Narmada Project, in an area susceptible to the kind of water table buildup found in the northwest, marks a different approach to that used in India in the past in that the drainage infrastructure is being put in right from the start of the investment.

6.10 Much less emphasis than under these projects has been put on drainage by most state governments. This lack of attention is reflected both as concerns the very limited investments made on drainage even where such investments are clearly needed, and in the inadequate provision of funds for maintenance of drains, in most states as little as 10 to 20 % of funding requirements. Those drains that have been constructed have been poorly maintained and are usually badly silted and overgrown with weeds.

6.11 Other actions that can help control waterlogging and salinization are improved water management and optimal conjunctive use of groundwater. A typical situation in most irrigated commands is overwatering in headreaches (and lack of water at the tail). This explains much of the localized waterlogging and salinization situations found in headends of command areas in peninsular India, and adds to situations where monsoon waterlogging is prevalent in eastern India. Also, progress can be made in better timing of irrigation so that it does not coincide with rains. Ideally, the crop should be under slight moisture stress just prior to a rainfall, optimizing both crop growth and providing greater soil absorptive capacity. In areas where groundwater is fresh, an important impact against a rising watertable is groundwater exploitation. This has been used to good environmental effect in large parts of the northwest. However, for some areas with particularly poor natural drainage, especially when coupled with poor groundwater quality, large investments in major drainage works may be necessary. From studies of Haryana, Punjab and Rajasthan, (UNDP, 1985 and Barber 1985) this appears to be the case in parts of northwest India. Finally, there is a need for a greatly stepped up research and monitoring program on waterlogging and salinity. Remedial actions and sizeable investments in drainage will be increasingly required if India's past and future investments in irrigation are to be sustainable.

C. Other Environmental Impacts

Nature of Environmental Problems

6.12 Siltation of reservoirs and canals is less an impact of irrigation than a consequence of upstream soil erosion on mainly rainfed lands resulting from the stresses imposed by climate and reductions in vegetative cover due to a large and growing human and animal population. Silt deposits affect canal maintenance costs. More important, siltation rates in reservoirs are generally much higher than assumed rates (Table 6.1). The eight sample reservoirs where observations of siltation were compared with assumed rates, all have higher siltation rates than assumed during scheme design, with expected life of the reservoirs averaging 35% of the life assumed at design. All reservoirs will eventually silt up as some soil erosion is inevitable. Also, if reservoir life turns out to be, say, 70 years instead of 200 years, the very marginal impact of discounted costs and benefits in such outer years will mean that the rate of return will not be markedly affected. However, the strategic need for long term sustainability of irrigation investments dictates that greater attention is paid towards realistic appraisal assessment of siltation rates. More fundamentally, and as much a benefit for rainfed farming, soil and water conservation practices for rainfed farming and maintenance of vegetative cover in forest and pasture lands are critically important to India's future agricultural performance. Initiatives such as the Bank-supported

watershed development projects[5] hold promise for eventual major impact on the sustainability of both rainfed and (indirectly) irrigated agriculture. Consideration should be increasingly given to a whole basin or sub basin approach to agricultural development. This is under consideration for the Narmada river basin (under the proposed Narmada River Basin Development Project) where a complete approach to rainfed agriculture and preservation of forest lands as well as irrigation development is being considered.

Table 6.1

Siltation of Selected Indian Reservoirs

Reservoir	Assumed Rate	Observed Rate	Expected Life as Percent of Design Life
	Acre-feet per annum		%
Bhakar	23,000	33,475	68
Maithon	684	5,980	11
Mavurakshi	538	2,080	27
Nizam Sugar	530	8,725	6
Panchet	1,982	9,533	21
Ramgange	1,089	4,366	25
Tungabhadia	9,796	41,058	24
Ukai	7,448	21,758	34

Source: Brown and Wolf, 1984.

6.13 River Flows. By altering river flows and sedimentation rates, surface and groundwater irrigation can affect, in particular, dry season flows and the courses of rivers. On the Periyar River, where 11 dams have been built, seawater now moves 20 miles upstream during the dry season, forcing factories near Cochin dependent on river water to close down. The deepwater port at Cochin is also silting up (Repetto 1986). Of greater concern in the longer term is the situation developing in the Ganga basin. The low flows on the rivers of the basin are now almost entirely intercepted by diversion structures for irrigation (and to some extent by reservoirs) located around the periphery of the great alluvial plain. Flows on the rivers below the structures during the low flow season are maintained almost entirely by outflows from groundwater, including return flows from irrigation which pass through the groundwater system. Flows now reaching Farakka barrage on the Ganga river during January to May are inadequate to meet the combined requirements for flushing of Calcutta port (via the Bagirallic distributary) and the needs of Bangladesh. There are

5 Watershed Development Projects, Hills and Plains (Cr. 2100/Ln. 3175 and Cr. 2131/Ln. 3197), both FY90, themselves based on earlier pilot projects and sector work.

large areas of the basin which are waterlogged; groundwater development here can only be beneficial and will have little impact on outflows until water levels are lowered by 1.5 - 2.0 m. However, in other localities of the basin, combined uncontrolled development of groundwater will eventually have an impact on groundwater outflows to the rivers of the basin and the low flows reaching Farakka.[6] The situation described above is not exclusive to the Ganga basin. In any river basin, the surface water and groundwater systems interact and form parts of the hydrological cycle which cannot be regarded independently. Proper water resource development in a basin should take account of this and the water system should be developed conjunctively.

6.14 Water Borne Diseases and Drinking Water Purity. The positive impact of irrigation development on human health probably greatly outweighs the negative consequences. Irrigation provides the means to improve diets, both in terms of calories and in supplementary protein, vegetables and milk through greater crop diversity and crop residues for fodder. This increases general health and disease resistance. Irrigation also provides water for bathing and washing of clothes and household utensils, all known factors in maintaining good health, and replenishes groundwater for drinking water purposes.

6.15 Nevertheless, a number of water-borne diseases - for example; malaria, schistosomiasis, typhoid, diarrhea, filariasis - can be spread through unsanitary water or presence of stagnant or slow moving water. The impact on the presence of such diseases of India's irrigation canals, drainage ditches and reservoirs must therefore be of constant concern (Akhtar and Learmonth, 1986). Some evidence exists demonstrating the expected conclusion that stagnant water sources in improperly managed surface schemes are harboring malaria vectors (Davidson, 1983). As concerns schistosomiasis, India has so far been an exception to schistosomiasis incidence in Latin America and Africa where the disease typically spreads rapidly. In India, only about three or four foci of schistosomiasis snails have been observed by representatives of the World Health Organization and the Indian Institute of Communicable Disease. The disease is very much localized and not spreading, but is being monitored and reasons for this atypical behavior studied (Chandiwana et. al., 1988). With regard to other diseases, information on the impact of irrigation for other diseases is diffuse, often inconclusive and frequently confined to data from specific areas. Knowledge of vector life-cycles, however, can be used to presume that risks are present and that sources of risk need to be monitored and controlled (De Wolfe, 1987). Removing sources of stagnant or slow moving water, frequently controllable by proper maintenance of drains and canals and efficient water management, is likely to have the largest mitigating impact.

6.16 Concerning chemical pollution, little is known about the extent of chemical pollution including impact of pesticides and soluble salts from fertilizers (such as nitrates) in water supplies as a result of intensive agriculture associated with Indian irrigation. Again, this merits monitoring and related research efforts to better assess the nature and degree of risk posed by any such impurities, and any necessary actions to remedy risk areas.

6.17 Flora and Fauna. Some examples of loss of flora and fauna due to irrigation are known and further cases can be presumed. Impacts include the obvious loss of habitat from flooding of lands for reservoirs, blocking of rivers used for spawning by dams, and changing of river flows which may reduce flushing out of river impurities and affect riverine and estuarine fish and other biota.

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[6] "Water Resources of the Ganges Basin, an Assessment of their Development, Availability and Demands" (Draft 1990, W. Price and W. M. Barber, World Bank).

Approach to Environmental Problems

6.18 The overview of issues above reveals a critical gap in terms of detailed field knowledge of what is actually happening and how, specifically, environmental issues can be addressed. On almost all environmental issues there is a dearth of good data. This is due to insufficient past and present monitoring and to the limited funds that have been provided for practical research. Many irrigation planners and practitioners lack the technical skills for environmental measurement and analysis. These problems are both a product of limited past emphasis on environmental problems and a still inadequate institutional and funding apparatus to instigate improvements.

6.19 Government and donor community efforts to deal with these issues have notably increased in the past decade. India's Department of Environment in the Ministry of Environment and Forests has mandated since 1985 an Environmental Impact Assessment for all irrigation projects presented for central Government financial assistance. This is to be commended and over time is likely to encourage greater environmental awareness, skills and knowledge. However, several current drawbacks in the system need attention. First, the environmental clearance process is frequently used simply as a delaying or blocking mechanism against any project with potential negative impact. Unfortunately, political pressures are frequently employed to get round this constraint with the result that projects with real environmental problems may be approved without the appropriate overview and addressment of environmental issues. A better approach would be an early assessment of environmental impact with a view to incorporating design features to minimize environmental damage. Project blockage may still be appropriate if satisfactory solutions cannot be found, but any decision should take into consideration full project costs, benefits and environmental impacts, rather than the single yardstick of environmental impact. Second, even with the environmental assessment process, project implementation often still falls short of addressing the environmental concerns and objectives identified in Environmental Impact Assessments.

6.20 Bank efforts to improve handling of environmental issues include the environmental assessments required for all projects since 1989, the funding of a number of project specific studies, and specific environmental components and monitoring actions incorporated in individual projects. For instance, the Upper Krishna Phase II Project (Cr. 2010/Ln. 3050), contains pilot actions to control against malaria .

6.21 Future improvement will require three main focuses. First, an institutional capacity is required in the irrigation sector to enable proper central overview of environmental policy and to act as a repository of expertise and data. This cell could also approve funding for environmental research and monitoring. Possibly, an existing institution could be adapted for this function. Second, the Government should significantly increase the funding of environmental research and monitoring. Third, project preparation must include environmental analysis of environmental issues and project design and costs must incorporate environmental components. These might include monitoring of environmental impact over time (eg. river and water table levels, soil composition, effect on wildlife, disease incidence, pollutant levels, etc.) and adaptations in design, construction and operations to incorporate environmental concerns.

D. Land Losses, Population Displacement and Deforestation

6.22 With the exception of groundwater irrigation, irrigation development will involve the displacement of at least some land towards canal and drainage infrastructure, and in schemes involving water storage, submergence for reservoirs. This is a cost, whether it involves the taking away of urban land, agricultural land, forest or marginal lands. To a greater or lesser extent, all such lands have some productive and/or ecological value. Further, without appropriate compensation and rehabilitation, the livelihoods of persons depending on such lands are

jeopardized. These costs vary depending upon the population pressure on the lands affected, the productivity and ecological value of the land lost, the type of irrigation investment, and the alternative opportunities open to displaced populations.

6.23 Run of the river type surface schemes, without storage, typically involve lands lost to canal infrastructure representing the area equivalent of some 2 to 5% of the irrigated command area created. With storage schemes, a further 3 to 8% of land is taken away as submerged land, a figure that varies widely depending on the suitability of the dam site and the size of the project. A dam blocking a deep valley (e.g. Sardar Sarovar Dam across the Narmada) has a smaller ratio of submerged land to newly irrigated land (2% in the case of Sardar Sarovar), whereas less ideal topography, such as Subernarekha (12% submergence ratio) presents much higher land submergence costs. There tends to be an inverse correlation between the size of a reservoir and the submergence ratio. Larger storage reservoirs usually involve smaller ratios of land lost to irrigation potential created. Thus, medium projects tend to have submergence ratios greater than 6% whereas on major schemes the ratio is usually smaller. Similarly, one large reservoir is usually more economical in terms of land losses than project designs involving several consecutive smaller reservoirs of equivalent total storage capacity. The extreme of this situation is found in many of the tank irrigation schemes of southern India where the ratio of land submerged to irrigated land can reach 1 : 1 (i.e., a submergence ratio of 100%).[7] Annex 6.2 presents data on submergence and families displaced for Bank assisted irrigation projects approved since the late 1970s. Summary results are presented in Table 6.2 below.

Table 6.2 Lands Lost and Population Displaced on Bank Irrigation Projects Approved between 1978 and 1988

Number of Projects	11
Land Irrigated ('000 ha)	3,617
Land Submerged ('000 ha)	143
Submergence Ratio (%)	3.9
Landowning Beneficiary Families ('000)	1,204
Estimated Total Beneficiary Families ('000)	2,400
Displaced Families ('000)	75
Displaced Families as % of Land Owning Beneficiary Families	6.2
Displaced Families as % of Total Beneficiary Families1/	3.1

1/ Assuming average ratio of landowning to total households of 50 % based on review of field studies.
Source : Partridge and Salam (ISR 1990)

6.24 Proposed Approach to Land Losses. The Forest Conservation Act of 1980, prohibits conversion of designated forest land[8] to non-forest use. This legislation has frequently resulted in blocked approval of storage based irrigation projects and has also complicated resettlement efforts. As discussed in Chapter II, future expansion of irrigation and other uses of water will depend increasingly upon exploitation of further water storage potential. This would require submergence of land for reservoirs, and in many cases submergence of designated forest lands. The concern with the deforestation problem is entirely legitimate and, indeed, the extent of the problem is widely underappreciated. Impoverishment of India's remaining forest resources is proceeding

[7] A discussion of the impact of reservoir size on land taken out of production viz a viz irrigation potential created is contained in R. B. Shah, "The Case for Big Dams", CWC, 1989.

[8] Lands classified as forests. Past depletion of tree cover has, however, resulted in deforestation of much of the designated forest land.

rapidly spurred by the combined pressures of tree felling for local household needs, overgrazing, inadequate control of the commercial timber lobby and encroachment for generally marginal returns of extensive rainfed agriculture. These impacts are all influenced by severe population pressure on the land and exacerbated by the general fragility of much of India's forest land occupying intrinsically poor soils susceptible to high erosion. Government estimates indicate that these pressures have resulted in an annual deforestation of up to 1.5 million hectares. On the other hand, a rough estimate of the total land lost (inclusive of forests) from reservoir inundation is far less. The development of new surface irrigation averaged 220,000 net hectares per annum between 1970-71 and 1984-85. Assuming for example that the growth of future surface irrigation development reaches 400,000 net hectares per annum and also a (high) submergence ratio of 8%, the lands submerged for reservoirs would be about 46,000 hectares per annum. Thus, the impact of irrigation development on deforestation is relatively small; 3% of total deforestation. Further, irrigation has mitigating impact on deforestation pressures. Irrigation development results in additional capacity for biomass creation (fodder, fuelwood) and reduces dependance on forest land of rural people (para 6.4). A more balanced approach when considering usage of such forest land for water development purposes is thus required. At the same time, the tackling of the main causes of deforestation noted above needs to be considerably stepped up.[9]

6.25 The question of the acceptability or otherwise of land loss and its impact on productivity and the environment is important and one that needs to be properly evaluated when considering the justification for an irrigation development proposal. A position that any loss of land is unacceptable is difficult to equate with the sizeable incremental productivity that can be created by irrigation investments. Similarly, ignoring this issue would be an error. An obvious approach is to quantify carefully the costs of such land losses which may vary considerably depending upon the type of project, the ratio of lands lost to lands brought under irrigation, the expected productivity of the irrigation investment and the economic and ecological value of the lands that would be lost. The question is more complex if land to be submerged has a value that is difficult to quantify; for instance, the ecological value of well forested lands, lands holding endangered flora and fauna, or lands of historical or spiritual significance. Quantification is here much more difficult if not impossible and involves a large element of judgement. It is suggested, however, that all such assessments should be made on as full an analytical base as possible, taking into account both costs and benefits, including presentation to decision makers of non-quantifiable factors. Reforestation components as part of irrigation development projects should also be considered. Under the Sardar Sarovar project (Cr. 1553), for instance, two hectares of land will be reforested for every hectare inundated.

E. Resettlement and Rehabilitation Policy

6.26 The data in Table 6.2 indicates that about 6 families are displaced per 100 families provided with irrigation, of which an estimated average of 3 families are displaced due to submergence of land for reservoirs and a further 3 families due to canal infrastructure. This situation is an evident cost of irrigation development. Unless these costs are compensated by alternative benefits through a good resettlement and rehabilitation (R&R) program, the social acceptability of irrigation development is in question. Past experience with R&R is reviewed below followed by a proposed policy and action program to address this issue.

Past Experience with Resettlement and Rehabilitation

6.27 Substantial progress has been made in the past few years towards establishing an approach

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9 Discussion of Indian deforestation and ecological degradation issues is contained in the following World Bank reports : Wasteland Development Review (1988), Review of Rainfed Agriculture and Watershed Development (1988), and Agricultural Technology Review (1989). A Review of the Forestry Sector is planned commencing in 1991.

towards R&R. The progress made, however, is concentrated on a few projects, generally Bank funded, and lacks a national policy and legal framework. For most irrigation projects, the past situation remains; oustees receive compensation but little assistance in rehabilitation as the concerns of local authorities cannot be translated into significant action. This is because of the lack of R&R policies at the state level, limited knowhow and funds, or absence of an R&R implementation apparatus. Recent pioneering work by Government and the World Bank with the assistance of NGOs, stands in contrast to the very incomplete Government and donor community understanding and resultant attention to R&R issues in the 1970s. A fundamental error was to assume that alternative Government land was available; in the event it seldom was. Another common mistake was to make provisions for cash compensation which were subsequently found to be inadequate for oustees to purchase land from other farmers. Also, tenant farmers, share croppers and agricultural laborers dependent on the land received no compensation for the loss of their livelihoods.

6.28 Dialogue between Government and the Bank on R&R issues increased through the 1980s which also witnessed a progressively better understanding of R&R issues by both Government and the donor and NGO community. In particular, a welcome turnaround is being implemented under the Sardar Sarovar Project (Cr. 1552/Ln. 2497, FY85), in the state of Gujarat, and some progress has been made in the Upper Krishna Phase II Project (Cr. 2010/ Ln. 3050, FY 89) in Karnataka. R&R under the Sardar Sarovar Project in Gujarat has involved some "learning by doing", but key features under this project now include: new state policies, an R&R Plan, establishment of minimum land areas for resettlement of oustees (in the case of Narmada a minimum of 2 ha per family member), provision of adequate funds for purchase of land by oustees, assistance in R&R through Land Purchase Committees and active support from Government staff and NGOs. Similarly, at the level of Government, much closer attention is now being paid to R&R. In 1989, a Draft National Policy on Developmental Resettlement was prepared jointly by NGOs and the GOI Commissioner for Scheduled Castes and Scheduled Tribes. At the level of individual states, an early initiative was taken in Maharashtra which passed the Maharashtra Project Displaced Persons Act of 1976 which defined the policies for resettlement of displaced persons into the irrigated commands of irrigation projects. Recently, similar legislation has been passed in Madhya Pradesh and Karnataka. However, throughout the rest of the country and in respect of many non–Bank–assisted projects even in Gujarat, piece-meal measures towards R&R have been adopted which have seldom been effective, suffering from inadequacies in policy guidance, the legal framework, detailed planning, and an insufficiently staffed administrative apparatus and lack of funding.

Proposed Future R&R Policy

6.29 Future resettlement and rehabilitation policy in India can be largely based on the experience gained over, in particular, the last several years [10]. The following principles and guidelines for future resettlement and rehabilitation policy and its implementation are proposed:

(a) The adequate handling of resettlement and rehabilitation (R&R) of communities displaced as a result of irrigation development is an essential requirement. This needs to be specifically addressed in national and state policy and legislation, in project feasibility analysis and in detailed project design, costing and implementation.

(b) The basic principle for R&R policy should be to recreate for displaced persons a situation allowing them to improve or at least regain the standard of living they had prior to displacement. through restoration of their productive capacity.

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[10] More detailed discussion is contined in "Land Acquisition, Resettlement and Rehabilitation", W. Partridge and A. Salam (ISR Background Paper, 1990).

(c) Resettlement and Rehabilitation Plans. For every project where land acquisition, resettlement and rehabilitation is required, a Land Acquisition Resettlement and Rehabilitation Plan should be prepared. This would require careful socio-economic and technical studies and would require a grass roots approach, closely involving the affected population, local authorities and NGO's.

(d) R&R as a Whole Community Approach. The needs of landed property owners are only one aspect to be considered. About 50 % of most rural communities may be landless. The needs of a diversity of households in the community need to be considered, including landed and landless families, artisans and shopkeepers, female headed households, tribal peoples and different ethnic groups. Needs such as availability of forest lands and grazing, of particular importance for tribal peoples and poorer groups, also need to be taken into consideration in project design and implementation of the project R&R component.

(e) Land as the Basic R&R Need. Provision of suitable replacement land for the community is the hub of a successful R&R program. An adequate exchange of land with similar income generating capacity is the critical community need, as the livelihoods of most groups depend, even if indirectly, on incomes generated from agriculture.

(f) Approaches to Provision of Land. Three approaches may be considered:

- Traditional Approach. The traditional approach is predicated on the assumption that adequate replacement land can be found without encroaching on already utilized land. While this approach may be part of the solution in any given situation, the general scarcity of land in India makes this strategy seldom totally applicable and often entirely inapplicable, a frequent problem encountered under Bank-assisted projects in the late 1970s and early 1980s. Where alternative government land is not available, other approaches involving giving up of lands by the downstream beneficiary population may be required.

- Provision of Land to Oustees by Beneficiary Farmers. One possible solution is to obtain agreement with irrigation beneficiaries that they will give up part of their lands for settlement by oustees, in return for provision of irrigation. Thus, in return for provision of irrigation on formerly rainfed lands, beneficiary farmers would be expected to give up, without compensation, some 5 to 15% of their land as well as agree to some associated land consolidation (the premise is that irrigation benefits would far outway such costs).

- Using Land Markets. A third alternative, a relatively new concept, is being piloted under the Upper Krishna Phase II project in Karnataka and in Gujarat under the Sardar Sarovar Project. These projects are making use of the land selling market that is stimulated under the impact of irrigation. Irrigation tends to cause land to become available. This is due to the

combined stimuli of the need for cash by newly irrigated farmers to invest in supplementary equipment and infrastructure, the greater management difficulties involved in handling an irrigated farm, and the applicability of state land ceiling laws which have lower thresholds for irrigated land (usually half the ceiling applicable for rainfed lands).[11]

The choice amongst these three alternatives, including the possibility of a combined approach, will be specific to the location concerned. In the case of the Sardar Sarovar Project, the land market approach is being applied with very positive initial experience. However, this approach is less likely to yield sufficient land where average farm holdings are small as in the case of much of east India. Similarly, in eastern India, unutilized land for the traditional approach is virtually unattainable, making the second approach (agreement with beneficiaries to give up part of their lands) possibly the most feasible. Another consideration relates to the budgetary costs of the third approach (land purchase costs may amount to some 10 to 15 % of project costs).

(g) Non-Land R&R needs. In addition to provision of land to the community, R&R programs will require a package of supporting actions. These are, typically: relocation and subsistence grants; assistance with the land purchasing procedure; access to institutional credit, inputs and extension services; support for other income generating schemes especially for landless and other poorer groups; and any necessary incremental community infrastructure such as roads, household water, schooling and health services.

(h) Implementing Authority. Under India's current administrative structure, the District Collector's office is the logical authority through which to implement any land acquisition and R&R program. The DC is the most senior officer in the district and has the authority to handle revenues and make adjudication decisions affecting land acquisition and settlement of disputes under the Land Acquisition Act. Creation of a Land Development Authority chaired by the DC to handle R&R, as under the Upper Krishna Project, is a useful model to follow. However, while the authority is proposed under the DC, an additional executive staffing structure would be required under the DC's chairmanship to implement the program, and adequate provision of funds for this unit's operations and in particular for funding land acquisition and R&R expenses would be needed. This unit would need to work closely with the Irrigation Department and command authority involved and with the local community and NGOs. Location of most of the staffing of this unit would need to be on site. An additional element for consideration is likely to be incorporation of the Panchayat administrative and consultative process which is gaining importance in several states.

(i) Time Sequencing. Lags between the vacating of lands and provision of irrigation benefits need to be taken into account. Some delays are usually inevitable but can be substantially reduced through better sequencing of works. If land consolidation is involved, it should be initiated several years in advance of resettlement to avoid time lags. Appropriate interim occupational and income support would nevertheless usually be required. Employment of such families on construction of the irrigation scheme is one approach which has been effectively used in several states.

(j) Implementation of R&R. Implementation of R&R should begin with detailed

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11 Partridge and Salam, (1990). Field survey data of land sales records in Shorapur taluk in the Upper Krishna command, illustrating the development of a land market with the advent of irrigation has also been collected by the Mysore Resettlement and Development Agency of Bangalore, an NGO in Karnataka.

surveys and grass roots consultation followed by preparation of a R&R Plan taking account of the considerations above. The R&R Plan should be thoroughly discussed with the local community and its key intentions and features published in the state Gazette. The Plan itself needs to be sufficiently detailed to form an action program including time sequencing, all administrative details and full costing of the program. This would then form the basis for project finalization, evaluation and costing. During implementation, the R&R program should be monitored and practical changes made to adjust against shortcomings.

(k) Establishment of a Policy and Legal Framework. Finally, while much can be done on a project specific basis within the existing legal framework, for more general application, there is a need for underpinning with a consistent policy and legal framework. It is recommended that a revised National Policy Paper on R&R should be prepared by GOI in conjunction with state Governments, establishing the policy framework and implementation guidelines for R&R. This should be followed by appropriate revision of the National Land Acquisition Act followed by the passing of any necessary related legislation at state levels.

6.30 The suggestions highlighted above are based on Government and World Bank experience during the last few years. As implementation experience progresses, improvement of the proposed approach is possible, and to this effect, studies and independent monitoring of R&R programs should be encouraged. Realism will be required in both implementation and in evaluation of R&R results. Creation of exactly similar situations and sources of livelihood is frequently not feasible, and particular problems emerge for accommodating groups such as tribal peoples where sources of livelihood are diffuse and not perfectly matched by provision of agricultural land. Nevertheless, under a well-designed R&R program, material welfare of displaced communities can be protected and if possible enhanced, and this needs to become a standard irrigation development practice.

Annex Table 1.1

Gross Value per Hectare of Irrigated and Unirrigated Land in Selected Major States, 1974-75 to 1978-79[1]

States	Rainfall (mm)	Value Productivity per Hectare of		Ratio of Irrigated & Unirrigated Yields	Percentage of Irrigated Area Under		
		GIA	GUIA (Rs/ha)	Per gross hectare	Canals	Ground water	Others
Andhra Pradesh	900	1953	716	2.7	47.4	17.0	35.6
Bihar	1260	1317	717	1.7	32.6	38.8	28.4
Gujarat	870	1999	749	2.7	17.3	79.8	2.9
Haryana	610	1935	580	3.3	59.1	40.6	0.4
Karnataka	840	2000	742	2.7	35.8	24.6	19.6
Madhya Pradesh	1140	1162	557	2.1	44.4	40.2	15.4
Maharashtra	870	1889	565	3.3	21.1	58.0	20.2
Orissa	1450	1254	865	1.4	64.3	12.5	22.2
Punjab	590	2355	890	2.6	44.2	55.5	0.3
Rajasthan	500	1253	355	3.5	34.9	54.1	11.0
Tamil Nadu	990	2490	813	3.1	35.5	33.9	39.4
Uttar Pradesh	1040	1788	805	2.2	34.6	56.8	8.6

GIA = Gross Irrigated Area GUIA = Gross Unirrigated Area

Source: Vaidyanathan (1987)

1 Estimated on the basis of irrigated and unirrigated area and yields of major crops published by the Dept. of Economics and Statistics, Min of Food & Agriculture, Government of India. In some cases output is assumed to be either wholly irrigated or wholly unirrigated. Value calculated at the average of all-India prices, in 1970-73 as estimated by Bhalla and Alagh (1979)

Annex Table 1.2

State-wise Relative Fluctuations in Production, Yield and Area of Irrigated and Unirrigated Crop Segments[1] During 1970-83

(Coefficient of Variation, %)

State	Irrigated Segment			Unirrigated Segment		
	Area	Yield	Output	Area	Yield	Output
Punjab	1.7	4.0	5.8	9.3	8.7	11.2
Haryana	2.1	8.7	8.2	11.5	19.6	25.3
Bihar	6.5	11.0	13.5	4.3	9.1	12.8
Uttar Pradesh	1.8	8.1	9.4	2.6	16.9	17.6
Madhya Pradesh	5.1	12.1	15.7	2.6	13.5	14.4
Gujarat	3.9	10.6	15.3	6.7	26.1	30.4
Maharashtra	9.3	7.6	12.7	5.6	14.1	16.8
Rajasthan	7.2	7.8	7.2	8.5	28.0	31.7
Andhra Pradesh	6.3	6.4	8.4	4.3	9.9	11.9
Karnataka	6.3	8.7	10.6	6.8	11.4	16.2
Tamil Nadu	9.7	6.0	13.0	8.1	14.4	18.9
Average	1.9	4.3	5.4	2.9	9.3	11.4

Source: Dhawan, (1988 p. 173).

1 Includes foodgrains and non-foodgrains.Based on an analysis of fluctuations in the aggregate data for the eleven States. Coefficients of variation are computed around the linear trend line fitted to the time series for the 14 year period, 1970-83.

Annex Table 1.3

Instability in Irrigated and Unirrigated Farming (1971 to 1984)* (standard deviation in annual growth rates)

State	Irrigated Segment			Unirrigated Segment		
	Area	Yield	Output	Area	Yield	Output
Punjab	1.7	4.2	4.9	13.6	12.1	19.3
Haryana	2.2	9.2	9.3	18.0	38.5	54.8
Bihar	5.8	18.0	22.0	6.0	13.9	17.9
Uttar Pradesh	2.4	10.6	12.0	3.5	36.5	40.0
Madhya Pradesh	6.7	20.0	24.5	3.1	22.5	23.0
Gujarat	10.4	18.0	23.8	10.9	67.3	86.3
Maharashtra	10.8	11.9	17.9	9.8	28.8	43.8
Rajasthan	10.2	9.4	11.3	10.5	39.7	46.9
Andhra Pradesh	8.6	8.4	13.6	5.5	16.4	18.8
Karnataka	11.3	11.7	16.7	10.6	20.7	31.4
Tamil Nadu	14.0	8.8	19.2	13.4	26.6	41.6
Average**	2.4	5.9	7.3	5.0	14.5	19.0

Note: * Pertains to all crops, foodgrains & non-foodgrains.

** Based on aggregate data of the eleven states.

Source: Rao et.al.(1988)

Annex Table 1.4

State-wise Percent Reduction in Output During Selected Droughts

State	Drought Year	Total Output		Foodgrains Output	
		Irrigated Agriculture	Unirrigated Agriculture	Irrigated Agriculture	Unirrigated Agriculture
Punjab	1974-75 (39)	8	(+) 1	10	(+) 3
	1979-80 (39)	Negl.	23	(+) 2	26
Haryana	1974-75 (30)	17	39	21	46
	1979-80 (42)	8	58	5	58
Bihar	1972-73 (30)	28	17	29	17
	1979-80 (11)	18	4	18	4
	1982-83 (38)	14	23	15	26
Uttar Pradesh	1974-75 (18)	5	19	10	22
	1979-80 (52)	20	52	16	52
Madhya Pradesh	1974-75 (17)	15	6	18	7
	1976-77 (8)	11	16	14	17
	1979-80 (36)	35	38	36	38
Gujarat	1972-73 (48)	24	62	30	47
	1974-75 (65)	27	62	23	54
Maharashtra	1972-73 (44)	18	54	47	53
	1982-83 (14)	9	16	25	16
Rajasthan	1972-73 (43)	Negl.	26	2	29
	1974-75 (25)	(+) 7	54	(+) 3	53
	1979-80 (13)	2	60	(+) 3	59
Andhra Pradesh	1972-73 (15)	11	6	12	9
	1979-80 (20)	11	2	8	(+) 3
Karnataka	1972-73 (25)	Negl.	34	1	31
	1976-77 (6)	18	36	23	35
Tamil Nadu	1974-75 (32)	22	26	29	36
	1980-81 (27)	4	45	11	43
	1982-83 (20)	21	20	26	28
All India	1972-73 (27)	7	20	8	18
	1974-75 (19)	7	13	10	14
	1979-80 (18)	10	20	6	22

Note: (+) indicates rise in output level.
Figures in parentheses indicate % deficiency in normal rainfall.
Negl. = negligible

Source: Dhawan, (1988).

Annex Table 1.5

Share of Non Cereals in Gross Agricultural Area
(Million Hectares, 1984-85 Provisional Data)

State	Cereals	Other Crops	Total Cropped Area	Percent Non Cereals
Andhra Pradesh	6.7	5.5	12.2	45
Assam	2.5	1.2	3.7	32
Bihar	8.1	2.2	10.3	21
Gujarat	3.9	6.4	10.3	62
Haryana	3.3	2.2	5.5	40
Himachal Pradesh	0.8	0.2	1.0	20
Jammu and Kashmir	0.8	0.2	1.0	20
Karnataka	5.8	5.9	11.7	50
Kerala	0.7	2.2	2.9	76
Madhya Pradesh	12.9	9.5	22.4	42
Maharashtra	11.3	9.1	20.4	45
Orissa	5.0	3.9	8.9	44
Punjab	5.1	1.9	7.0	27
Rajasthan	8.3	9.0	17.3	52
Tamil Nadu	4.0	3.1	7.1	44
Uttar Pradesh	17.7	7.4	25.1	29
West Bengal	5.6	2.0	7.6	26
Other States/Territories	1.5	0.1	1.6	6
All India	104.0	72.0	176.0	41

Source: Provisional data for 1984-85 from Directorate of Economics and Statistics. Includes both Irrigated and Rainfed lands.

Annex Table 1.6

Labor Utilization on Rainfed and Irrigated Crop in God Canal Area in Maharashtra and Rajasthan

	(Mandays/Ha)			
	Maharashtra		Rajasthan	
	Rainfed	Irrigated	Rainfed	Irrigated
Local Jowar	38	68	-	-
Hybrid Jowar	51	75	-	-
Local Bajra	57	80	14	48
Hybrid Bajra	-	80	-	-
Wheat	-	73	-	-
Paddy	-	85	-	-
Gram	-	57	21	41
Sugarcane (Adsali)	-	326	-	-
Groundnut	-	88	25	65
Per Hectare Crop Production as a whole	-	75	16	46

Source: Patil, R.G., et. al. (1980), Roy (1983)

Annex Table 1.7

Per Hectare Mandays of Human Labor Use Before and After Well Irrigation in Karnataka

Size Group (Hectares)	(Mandays/Ha) Own Labor		Hired Labor		Total		
	Before Irrigation	After Irrigation	Before Irrigation	After Irrigation	Before Irrigation	After Irrigation	Additional Hired Labor
1	2	3	4	5	6	7	8 = (5-4)
Up to 1.00	89	131	16 (15)*	120 (48)	105	251	104
1.00 - 2.00	65	111	30 (31)	126 (53)	95	237	96
2.00 - 4.00	52	101	33 (39)	121 (55)	85	222	88
4.00 & Above	48	77	28 (37)	116 (60)	76	153	88
All Size	56	99	29 (34)	120 (55)	85	219	91

* Figures in brackets indicate proportion of hired labor to total labor input.

Source: Kamble et. al., 1979.

Annex Table 1.8

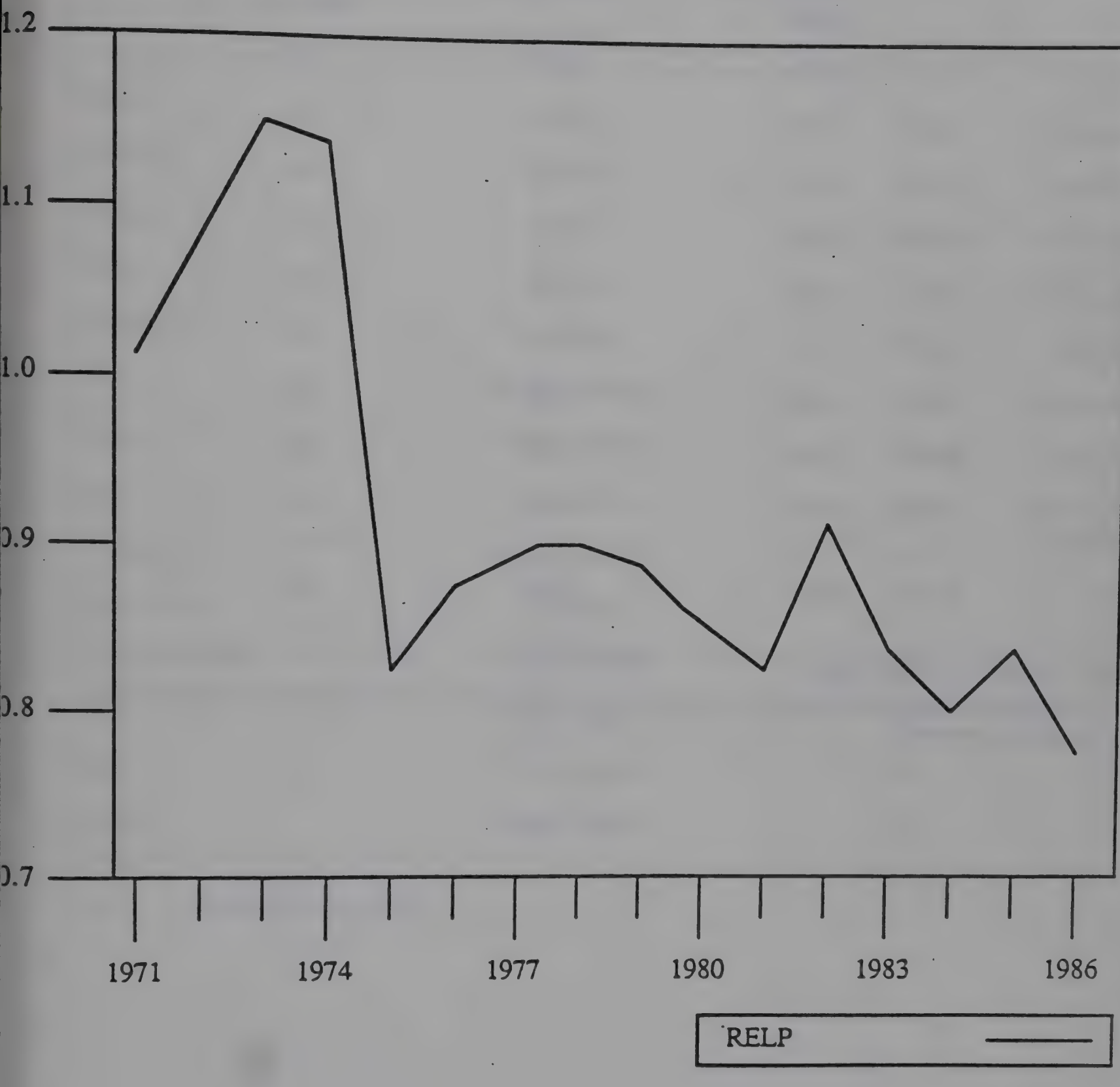
Indicators of the Spread of Improved Agricultural Technology, by State

State	Average Annual Growth Rate of Foodgrain Production 1967/68 - 1981/82 (%)	Shares of Gross Cropped Area under Irrigation 1978/79 (%)	Shares of Foodgrain Area under HYVs 1981/82 (%)	Short-Term Credit Advanced per ha of Gross Cropped Area 1982/83 (Rs.)	Fertilizer Use per hectare of Gross Cropped Area 1982/83 (kg./ha)	Tractors per 1000 ha 1981 (No.)	Oil Engines & Electric Pumpsets per 100 ha of Gross Cropped Area 1981 (No.)	Share of Holdings having Iron Ploughs 1977 (%)	Electric Power Use per Capita in Agriculture 1979-80 (kWh)	Surfaced Roads (Length per '000 sq. km) 1978/79 (km)
Andrha Pradesh	3.3	35.8	58	123	53	1.6	5.2	2	19.3	38
Assam	1.1	17.3	42	4	4	0.8	0.1	2	0.1	73
Bihar	0.6	32.6	58	26	18	1.7	2.9	2	3.9	46
Gujarat	3.3	18.6	55	111	39	2.7	9.2	8	36.6	27
Haryana	3.6	53.9	77	319	47	14.0	6.0	22	71.7	67
Himachal Pradesh	1.0	16.7	61	27	20	1.6	0.3	8	1.3	43
Jammu & Kashmir	2.4	40.9	61	58	32	2.0	0.2	6	3.9	8
Karnataka	2.2	15.4	43	71	38	1.3	3.5	14	9.9	55
Kerala	0.1	12.3	53	718	37	1.1	4.4	8	3.9	232
Madhya Pradesh	0.8	11.1	28	70	11	1.2	2.2	2	6.3	23
Maharashtra	5.2	11.6	41	132	26	1.3	4.8	8	21.5	53
Orissa	1.0	19.2	31	60	11	0.4	0.5	4	1.3	74
Punjab	5.9	83.0	93	478	128	21.8	9.8	96	113.0	91
Rajasthan	1.7	19.7	25	58	9	2.2	1.7	5	23.5	18
Tamil Nadu	1.1	49.7	80	104	59	2.0	14.8	8	45.0	130
Uttar Pradesh	2.3	43.5	56	83	61	4.6	6.2	13	23.0	64
West Bengal	0.9	19.6	37	40	33	0.5	1.8	1	1.4	158
All India	2.5	27.7	48	113	37	3.0	4.6	9	19.3	49

Source: Agricultural Technology Review, draft September 1989, World Bank. Based on MOA, Directorate of Economics and Statistics data.

Annex Table 1.9

Ratio of Foodgrain Prices to Prices of All Commodities in India – 1970/71 to 1986/87



Source: Wholesale Price Indices. Base 1970/71 = 100 for both series.
Last Week Series for Foodgrains, Average Series for All Commodities

Annex Table 3.1: Plan Outlays on Major and Medium Irrigation Projects
(Rs. Million)

Plan Period		Outlays at Constant Prices (85-86)a/	Potential Created (in million ha)	Derived Cost per Hectare of Potential Created (Rs. '000)
First Plan	(51-56)	55,784	2.48	22.5
Second Plan	(56-61)	47,652	2.14	22.3
Third Plan	(61-66)	59,611	2.24	26.6
Annual Plan	(66-69)	35,458	1.53	2.32
Fourth Plan	(69-74)	75,828	2.61	29.0
Fifth Plan	(74-78)	94,017	4.01	23.4
Annual Plan	(78-80)	58,596	1.89	31.0
Sixth Plan	(80-85)	132,642	3.40	39.0
Seventh Plan (anticipated)	(85-90)	113,430	3.13	36.2
Total	(51-90)	673,018	23.43	28.7

Source: Government of India, 1989.

a/ Current prices adjusted to 85-86 prices by wholesale price index. Outlays are combined Plan outlays of Central and state governments.

Annex Table 3.2 Economic Rate of Return at Project Completion for Government Surface Irrigation Projects

Project	State	Ex-Post (ERRs) %
Palamau	Bihar	11.8
Fatewadi	Gujarat	15.7
Panam	Gujarat	9.8
Watrak	Gujarat	9.2
Dantiwada	Gujarat	7.3
Tawa	Madhya Pradesh	-1.4
Girna	Maharashtra	10.7
Ghod	Maharashtra	6.9
Pochampad	Andhra Pradesh	6.2
Mukarthihal	Karnataka	18.7
Cauvery-Mettur	Tamil Nadu	7.1
Sarda	Uttar Pradesh	7.3
Tarai	Uttar Pradesh	4.8
Salwa	Uttar Pradesh	4.6

Source: Daines & Pawar (1987).

Annex Table 3.3

Agricultural Operations Evaluated in India 1974-88 By Year of Evaluation and Approval

OED ID	Project Description	Eval Year	Approval Year	Est. Comp	Act. Comp	Est Cost	Actual Cost	Est. ERR[1]	Act. ERR[2]	Rating[3]	Ln/Cr.
C0191	Gujarat Agricultural Credit	76	70	15-Jun-74	15-Apr-75	67		23	28	S	C0191
L0614	Tarai Seeds	79	69	15-Dec-74	15-Sep-78	22.4	21.8	17	18	S	L0614
C0226	Andhra Pradesh Agri-cultural Credit	79	70	15-Nov-73	15-Jul-77	45.1	43.7	30	37	S	C0226
C0203	Punjab Agricultural Credit	79	70	15-Dec-72	15-Dec-76	40	42.7	14		S	C0203
C0249	Haryana Agricultural Credit	79	71	15-Dec-74	15-Jul-76	44.5	53	21	50	S	C0249
C0250	Tamil Nadu Agricultural Credit	79	71	15-Dec-74	15-Dec-77	62	62	28	35	S	C0250
C0293	Maharashtra Agricultural Credit	79	72	15-Sep-75	15-Mar-76	53.4	57	41.5	34	S	C0293
C0391	Madhya Pradesh Agricultural Credit	79	73	15-Dec-76	15-Dec-76	60.3	69.9	58.5	45	S	C0391
C0540	Agricultural Refinance & Development Corp.	79	75	15-Dec-77	15-Jun-77	168.5	179	31.5	34	S	C0540
C0278	Karnataka Agricultural Credit	80	71	15-Jul-75	15-Mar-77	70.4	74.5	26.5	35	S	C0278
C0392	Uttar Pradesh Agricultural Credit	80	73	15-Sep-76	15-Dec-77	72.5	79.8	25.5	32	S	C0392
C0267	Wheat Storage	81	71	15-Dec-74	15-Mar-80	15.9	20.2	25	15	S	C0267
C0294	Bihar Agricultural Markets	81	72	15-Jun-78	15-Jun-80	23.3	28.8	29	11	S	C0294
C0440	Bihar Agricultural Credit	81	73	15-Jun-77	15-Dec-79	60	51	26.5	28	S	C0440
C0715	Agricultural Refinance & Dev. Corp. Credit (ARDC) 2	81	77	15-Dec-79	15-Dec-79	467	488	38.5	36	S	C0715
C0526	Drought Prone Areas	82	74	15-Mar-80	15-Jun-81	102.7	84.3	24.5		S	C0526
C0378	Karnataka Agricultural Wholesale Markets	84	73	15-Dec-79	15-Dec-82	11.9	16.1	15	7	U	C0378
C0456	Himachal Pradesh Apple Processing & Marketing	84	74	15-Mar-78	15-May-82	21.7	19.2	23	1	U	C0456
C0609	Madhya Pradesh Forestry Technical Assistance	84	75	15-Apr-81	15-Mar-83	8.2	6			U	C0609

[1] Economic Rate of Return as estimated at appraisal.

[2] Economic Rate of Return as estimated at project completion.

[3] S = "satisfactory", U = "unsatisfactory"

Annex 3.3 (continued)

OED ID	Project Description	Eval Year	Approval Year	Est. Comp	Act. Comp	Est Cost	Actual Cost	Est. ERR[1]	Act. ERR[2]	Rating	Ln/Cr. #(1)
C0737	Rajasthan Agricultural Extension and Research	85	77	15-Oct-82	15-Mar-83	26.6	25.2			S	C0737
C0947	Agricultural Refinance & Dev. Corp. Credit (ARDC) 3	85	79	15-Dec-81	15-Dec-81	686	758	39.5	1	U	C0947
C0712	Madhya Pradesh Agricultural Extension & Research	86	77	30-Sep-83	30-Sep-83	20.86	18.4			S	C0712
C0682	Orissa Agricultural Devel.	86	77	31-Dec-83	30-Jun-84	40	35.3			S	C0682
C0728	Assam Agricultural Devel.	86	77	31-Mar-83	31-Mar-85	16.4	11.6			S	C0728
C0862	Composite Agricultural Ext.	86	78	31-Dec-84	30-Jun-85	53.4	77.5			S	C0862
C0522	Madhya Pradesh Dairy	87	74	15-Jun-82	15-Mar-83	31.2	24.1	34	-5	U	C0522
C0521	Rajasthan Dairy Development	87	74	15-Dec-82	15-Dec-83	51.8	39	31	28	S	C0521
C0482	Karnataka Dairy Development	87	74	15-Sep-82	15-Sep-84	63.7	43.1	33	22	S	C0482
L1273	National Seed 1	87	76			52.7	42.7	65	11	U	L1273
C0690	West Bengal Agricultural Extension & Research	87	77	15-Mar-82	15-Mar-84	28.2	18.22			U	C0690
C0761	Bihar Agricultural Extension and Research	87	77	15-Oct-83	15-Mar-85	16	32.7			S	C0761
L1394	Gujarat Fisheries	87	77	15-Dec-81	15-Jun-86	38	34.9	24	16	S	L1394
C0871	National Cooperative Development Corp. (NCDCI)	87	78	15-Dec-83	15-Dec-84	63.9	66.4	22	11	S	C0871
C0815	Andhra Pradesh Fisheries	87	78	15-Mar-82	15-Jun-86	36.5	25.66	35		U	C0815
C0824	National Dairy	87	78	15-Dec-85	15-Dec-85	319.2	240.3	28	25	S	C0824
C0816	National Seed 2	87	78			34.86	27.21	158	11	U	C0816
C0747	Foodgrain Storage 2	88	77	15-May-82	14-May-85	215.5	230	19	20	S	C0747

Source: Operations Evaluation Department, World Bank.

Annex Table 3.4

A Comparison of Appraisal and Actual ERRs in Irrigation and Drainage Sector in Asia

(From 1989 Bank-Wide Audits of Irrigation Projects)

Country	Project	Loan/Credit (Actual) US$ Million	ERR	
			Appraisal	Actual (Audit)
China	North China Plain	54	30	56
India	Punjab Irrigation	129	36	36+
Philippines	National Irrigation and Systems Improvement	65	23	22
Indonesia	Irrigation XIV	116	25	10
	Magat Riv. Multipurpose (I, II, III)	218	13	9.5
Pakistan	Khairpur Drain. & Irr.	14	17	8
Philippines	Chico River	34	15	7.7
Thailand	Mae Khlong	57	23	7.2
Indonesia	Irrigation (RD)	107	14	6.0
Thailand	Phit Sanolol	88	20	4.8
Indonesia	Irrigation XVI	37	18	4.0
Vietnam	Dan Tieng Irrigation	60	17	4.0

Source: Annual Review of Evaluation Results for 1989; Agriculture and Rural Dev. Sector 1990, OED, World Bank.

Annex Table 3.5

Analysis of Economic Rates of Return (ERR) for Bank-Funded Projects: Appraisal and PCR Estimates

		Mahanadi Barrages (Cr. 1078-IN)	Subernarekha (Cr. 1289)	Gujarat II (Cr. 1011)	M.P. Chambal II (Cr. 1288)	M.P. Medium (Cr. 1108)	Andhra Pradesh (Cr. 1116)	Karnataka Tanks (Cr. 1116)	Kallada Irr & Tree Crops (Cr. 1269)
1.	Appraisal ERR	21.0	17.3	18.0	35	18.0	15.0	20.0	20.0
2.	Current ERR	14.1	7.2	3.2	9.9	5.1	3.2	3.6	7.2
3.	Increase in Real Capital Cost (%)	49	148	108	95	116		51	60
4.	Fall in Rupee Price of Paddy (%)	21	45				25		
5.	Delay in Benefits	Slight	Serious	Serious	Moderate	Serious	Moderate	Serious	Serious
6.	Reduction in CCA (%)2/	-	-	16	-	-	-	4	-
7.	Increase in CCA (%)2/	-	-	-	-	-	-	-	33
8.	Total Capital Costs (Rs. Million; 1989-90 Price)	1382	18613	6989	1083	5891		1486	2821
9.	C.C.A. (000 ha)2/		255	175	221	127.6		24.1	50
10.	Capital Cost per Ha (1989-90 prices, Rupees)		73000	39800	49001/	46160		61741	56420

Source: Venkataraman, (ISR note 1990).

1/ Modernization project involving minor works relative to whole command area.

2/ CCAs (Culturable Command Areas) in row 9 refer to eventual CCAs assumed at PCR stage. In only 3 projects were the eventual CCA assumptions at appraisal modified at the PCR stage (rows 6 & 7)

Annex Table 5.1

Non-Plan Expenditure on Major & Medium Irrigation Projects
(In Rs Million at 1980-81 prices)

State	1980-81	1988-89	Percent Increase/Decrease
Punjab	166	732	340
Haryana	336	720	114
Bihar	110	464	320
Uttar Pradesh	697	2,676	290
Orissa	175	128	- 28
West Bengal	131	552	320
Madhya Pradesh	127	230	80
Gujarat	318	800	150
Maharashtra	766	2,080	170
Rajasthan	379	2,000	430
Andhra Pradesh	581	2,715	370
Karnataka	518	910	75
Tamil Nadu	242	425	75
Kerala	76	170	120
ALL STATES	3,930	15,000	280
Non-plan expenditure on Irrigation as % of total non-plan expenditure (All states)	3.9	6.3	

Source: Reserve Bank of India Bulletins - August, 1981; December, 1989
a/ For 14 states above.

Annex Table 5.2

Capital Disbursements of Plan Outlays for Irrigation Sector: 1980-81 and 1988-89

(In. Rs. Million at 1980-81 Prices)

State	1980-81	1988-89	Per cent increase (+) decrease (-)
Punjab	448	408	- 10
Haryana	581	420	- 28
Bihar	1,425	1,706	+ 20
Uttar Pradesh	1,969	2,950	+ 50
Orissa	1,128	1,100	- 3
West Bengal	626	445	- 30
Madhya Pradesh	1,059	2,025	+ 90
Gujarat	991	834	- 16
Maharashtra	1,719	2,740	+ 60
Rajasthan	739	1,100	+ 50
Andhra Pradesh	1,337	2,090	+ 56
Karnataka	780	860	+ 10
Tamil Nadu	230	275	+ 20
Kerala	435	350	- 20
ALL STATES a/	13,954	18,260	+ 31

Sources: Reserve Bank of India Bulletins: August 1981, December 1989
a/ For 14 states above.

Annex Table 5.3

Plan Outlays and Non-Plan Expenditures on Major and Medium Irrigation Projects: 1988-89
(In Rs Million at 1980-81 prices)

State	Plan Outlays	Non-Plan	Plan Outlays as Ratio of Non-Plan Expenditures
Punjab	408	732	0.56
Haryana	420	720	0.58
Bihar	1,706	464	3.68
Uttar Pradesh	2,950	2,676	1.10
Orissa	1,100	128	8.6
West Bengal	445	552	0.80
Madhya Pradesh	2,025	230	8.80
Gujarat	834	800	1.04
Maharashtra	2,740	2,080	1.32
Rajasthan	1,100	2,000	0.55
Andhra Pradesh	2,090	2,715	0.77
Karnataka	860	910	0.95
Tamil Nadu	275	425	0.65
Kerala	350	285	1.23
ALL STATES a/	18,260	15,000	1.22

Source: Reserve Bank of India
a/ For 14 states above.

Annex Table 5.4

Capital Disbursements of Plan Outlays for Irrigation as per cent to Total Outlays by States

State	1980-81 (%)	1988-89 (%)
Punjab	21	11
Haryana	34	24
Bihar	40	34
Uttar Pradesh	30	31
Orissa	62	38
West Bengal	21	13
Madhya Pradesh	26	38
Gujarat	31	23
Maharashtra	32	38
Rajasthan	32	35
Andhra Pradesh	45	52
Karnataka	34	27
Tamil Nadu	18	16
Kerala	30	24
ALL STATES a/	30	28

Source: RBI Bulletin (August & December 1989)
a/ For 14 states above.

Annex Table 5.5

Cost of Establishment and Works in Maharashtra & Bihar
(In Rs. Million)

Particulars Increase	Bihar			Maharashtra		
	80-81	84-85	% Increase 84-85 over 80-81	79-80	83-84	% Increase 83-84 over 79-80
Establishment	9.1	32.7	259	59.8	116.0	94
Works	50.2	48.4	- 4	45.8	108.4	137
Sub-total	59.3	81.1	37	105.6	224.4	113
Revenue Establishment	29.8	63.6	113	n/a	n/a	n/a
TOTAL	89.1	144.7	62	105.6	224.4	113

Source: R. Bhatia (1989), Pawar (1985).

Annex Table 5.6

Cost of Establishment, Works and Revenue Collection for Sone and Kosi Project in Bihar

(In Rs. Millions; Current Prices)

Particulars	Sone Command			Kosi Command		
	80-81	84-85	% Increase 84-85 over 80-81	79-80	83-84	% Increase 83-84 over 79-80
1. Establishment Costs	5.9	11.1	88	2.5	20.8	732
2. Works	12.8	13.4	5	33.6	30.1	- 11
3. Sub-total (1+2)	18.7	24.5	31	36.1	50.9	41
4. Cost of Revenue Collection	19.1	39.5	106	10.7	24.1	125
5. Total (3+4)	37.8	63.0	66	46.8	75.0	60

Source: R. Bhatia (1989)

Annex Table 5.7

O & M Costs in Gujarat
(Rs/Hectare)

Name of Project	Year	Maintenance & Repairs	Establishment	Total O & M
Danti Wada				
	1982-83	49	29	78
	1985-86	56	78	134
		(14)	(169)	(72)
Kakarpar				
	1982-83	74	44	118
	1985-86	70	93	163
		(-5)	(111)	(38)
Mahi				
	1982-83	67	54	121
	1985-86	83	87	170
		(24)	(61)	(40)
Shetrunji	1982-83	75	25	100
	1985-87	71	45	116
		(-5)	(80)	(16)

Note: Figures in parentheses are percentage increase 1985-86 over 1982-83.

Source: H. Patel, 1989.

Annex Table 5.8

Resource Flows Related to Irrigation Financing in Bihar
(Current Revenues and Expenditures Only, 1984-85)

A. Resource Flows into Irrigated Agriculture	Annual Flows (Current expenditures only) (Rs. Million)
1. Surface Irrigation Projects	
O&M Expenses	167.6
Direction & Administration	4.5
Revenue establishment	70.7
Sub-total	242.8
2. State Tubewell Projects	
O&M Expenses (including revenue collection establishment)	90.3
Electricity costs	59.3
Sub-total	149.6
3. Private Tubewells	
Subsidy on Electricity Charges	868.0
4. Fertilizer subsidy on imported fertilizers used on irrigated land	314.0
5. Sub-total for the government-managed irrigation (1 & 2)	392.4
6. Sub-total for irrigation including electricity subsidies for private tubewells (1&2&3)	1,260.4
7. Total for irrigated agriculture including fertilizer subsidies (1&2&3&4)	1,574.4

Annex Table 5.8 (continued)

B. Resource Flows Out of Agriculture	Current Revenue Flows (Rs. Million)
1. Land Revenue & Agriculture Income Tax:	
Gross Collections	84
Less Cost of Collection	93
Net revenues	-9
2. Irrigation Sector	
Direct receipts	
Gross Collections of Irrigation Charges	126.4
Other receipts	N.A.
Sub-total	126.4
Indirect receipts	
Cess on Commercial Crops	N.A.
3. Indirect Taxes/Revenues	
Additional incidence of indirect taxes on households (Canal irrigation farms only)	622
Share of indirect taxes on agro-processing industries	-
Share of direct taxes on manufacturing	-
Export revenues attributable to irrigation	-
Reduction in import revenue to irrigation	-
4. Sub-total (2 & 3)	748.4

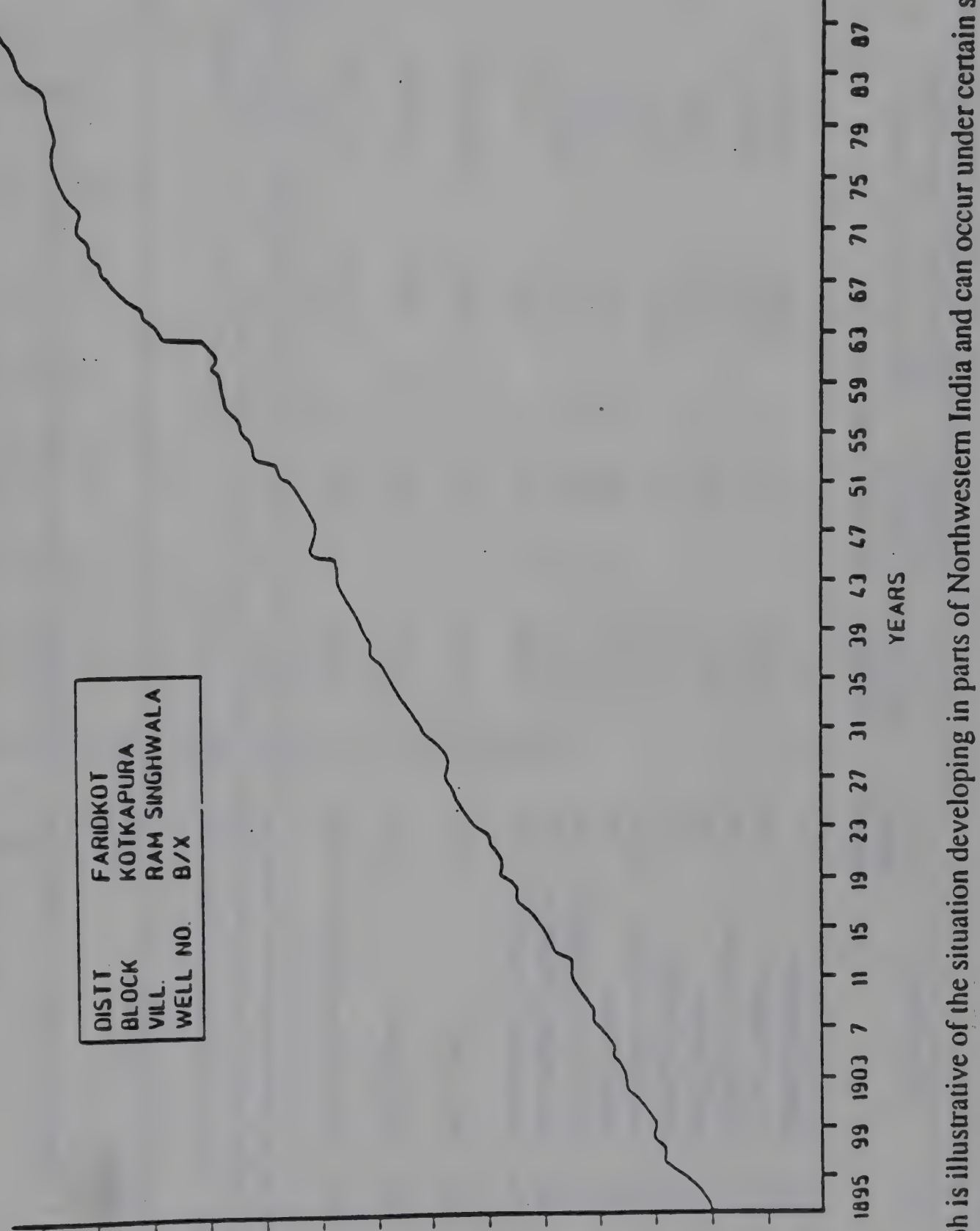
C. Net Financial Flows (Excluding Land Revenue)	(Rs. Million)
1. Net financial flows for canal irrigation	748.4 - 242.8 = 505.6
2. Net financial flows for Government-managed irrigation	748.4 - 392.4 = 356.0
3. Net financial flows for irrigated agriculture	826.0

Source: R. Bhatia (1989)

Annex Figure 6.1

Annex: Figure 6.1

Impact of Irrigation on the Water Table in Parts of Northwestern India
(Typical well hydrograph of Southwestern region of Punjab)



Note: This hydrograph is illustrative of the situation developing in parts of Northwestern India and can occur under certain soil-water and irrigation conditions.

Annex Table 6.2

Relationship Between Net Area Irrigated and Area Submerged On Bank Financed Irrigation Projects (1978-88)

Report No.	Loan/ Credit No.	FY	Project Name	No. of Displaced Families*	No. of Beneficiary Families*	% Displaced Families/ Beneficiary Fam.	Area of Land Submerged (Ha)	Area of Land Irrigated	% Land Submerged/ Irrigated
1835A-IN	Cr. 788	78	Karnataka Irrigation	**	**	**	**	**	**
2843-IN	Cr. 1011	80	Gujarat Irrigation II	3,820	136,000	3%	10,600	190,100	6%
3260-IN	Cr. 1108	81	MP Medium Irrigation	3,450	29,700	12%	1,327	107,000	1%
2147A-IN	Ln 1897	81	Kandi Watershed	364	16,000	2%	270	3,000	9%
3458-IN	Cr. 1177	82	MP Major Irrigation	2,720	115,700	2%	5,820	360,000	2%
3948-IN	Cr. 1289	83	Subernarekha Irrigation	10,000	130,000	8%	30,000	255,000	12%
3657-IN	Cr. 1269	84	Kallada Irrigation	450	75,000	1%	2,300	37,600	6%
5028-IN	Cr. 1496	84	Gujarat Medium Irrigation	16,360	94,200	17%	21,095	336,000	6%
4448-IN	Cr. 1397	84	Orissa Medium Irrigation	3,270	100,000	3%	15,114	108,000	14%
5376-IN	Cr. 1621	86	Maharashtra Comp. Irr. III	3,270	66,400	5%	7,686	92,000	8%
5107-IN	Ln. 2497/ Cr. 1552	86	Sardar Sarovar	16,360	340,000	5%	41,000	1,900,000	2%
5883-IN	Ln. 2662/ Cr. 1665	87	AP Irrigation II	14,540	101,100	14%	7,365	228,000	3%.
7406-IN	Ln. 3050/ Cr. 2010	88	Upper Krishna Irrigation II	40,000	94,280	42%	41,000	575,000	7%

* Displaced families includes landless agricultural laborers and landowning families, as well as artisans and service workers in the non-agricultural sectors, whereas beneficiary families includes only landowning families. It should be noted also that benefitting families reflect the landholding pattern at the time of project appraisal, not the actual number of families benefitting resulting from normal subdivision and sale of parcels following introduction of irrigation.

** Resettlement in FY78 Karnataka Irrigation Project was not successful and the backlog of resettlement work is now being carried out under FY88 Upper Krishna Irrigation II Project.

Source: W. Partridge and A. Salam,Land Acquisition, Resettlement and Rehabilitation, Irrigation Sector Review, World Bank, 1990

Annex Table 7.1

Plan Outlays on Irrigation
(Rs In million)

Plan Period	Irrigation & Flood Control	Agriculture & Allied Sectors	Total Plan Outlays
Third Plan (61-66)	10,889 (12.7)	6,647 (7.8)	85,765
Annual Plans (66-69)	10,071 (16.7)	4,710 (7.1)	66,254
Fourth Plan (69-74)	23,204 (14.7)	13,541 (8.6)	157,788
Fifth Plan (74-79)	48,649 (12.3)	38,765 (9.8)	394,262
Annual Plan (79-80)	19,965 (16.4)	12,879 (10.6)	121,765
Sixth Plan (80-85)	66,235 (6.1)	109,299 (10.0)	1,092,917
Seventh Plan (85-90)	105,236 (5.8)	169,786 (9.4)	1,800,000

Note: Figures in brackets show percentage to Total Plan Outlays.

Source: Economic Survey (1989-90)

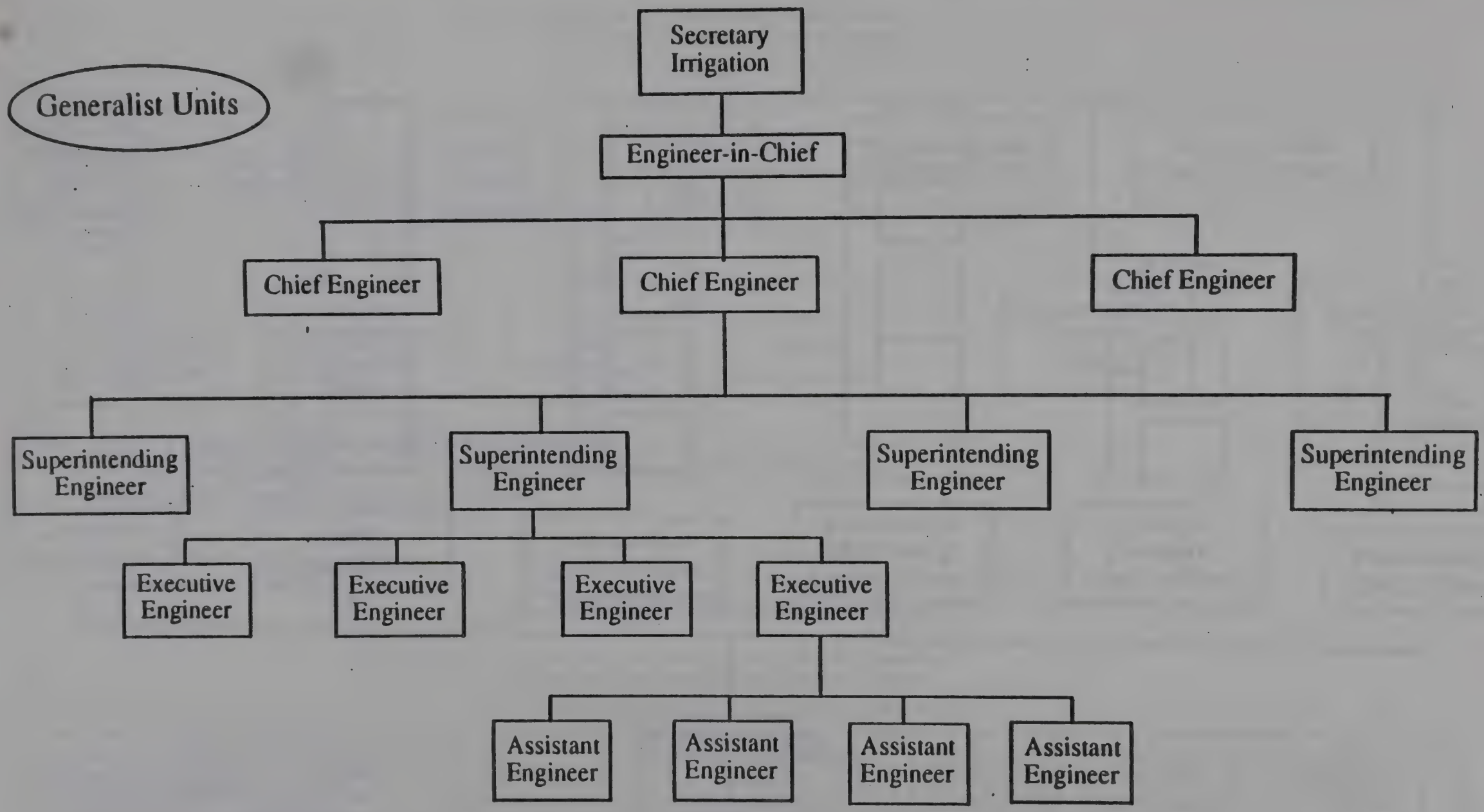
Annex Table 7.2

Irrigated Areas in India and Other Countries
(Million Hectares)

		India by States (1984)		Country Comparison (1986)	
		Net Irrigated Area	Gross Irrigated Area	Gross Irrigated Area	
India	Total	41.8	54.1	India	56.0
By State	Andhra Pradesh	3.5	4.5	China	46.6
	Bihar	2.8	3.8	USA	23.0
	Gujarat	2.2	2.6	USSR	21.0
	Haryana	2.2	3.5	Pakistan	16.0
	Karnataka	1.7	2.1	Indonesia	7.3
	Madhya Pradesh	3.0	3.1	Mexico	5.3
	Maharashtra	2.0	2.7	Egypt	3.2
	Punjab	3.6	6.3	Brazil	2.7
	Rajasthan	3.2	3.8	Bangladesh	2.4
	Tamil Nadu	2.6	3.5	Argentina	1.7
	Uttar Pradesh	9.9	12.1	Philippines	1.5
	West Bengal	2.0	2.0	Morocco	1.3
	Orissa	1.5	2.0	South Korea	1.1
	Other States and Territories	1.7	2.1	Burma	1.1
Source:	Indian Agriculture in Brief (22nd Edition).			Source: Irrigation and Drainage Research, ICID, February 1990; based on FAO 1987 Productive Year Book (1986 Data).	

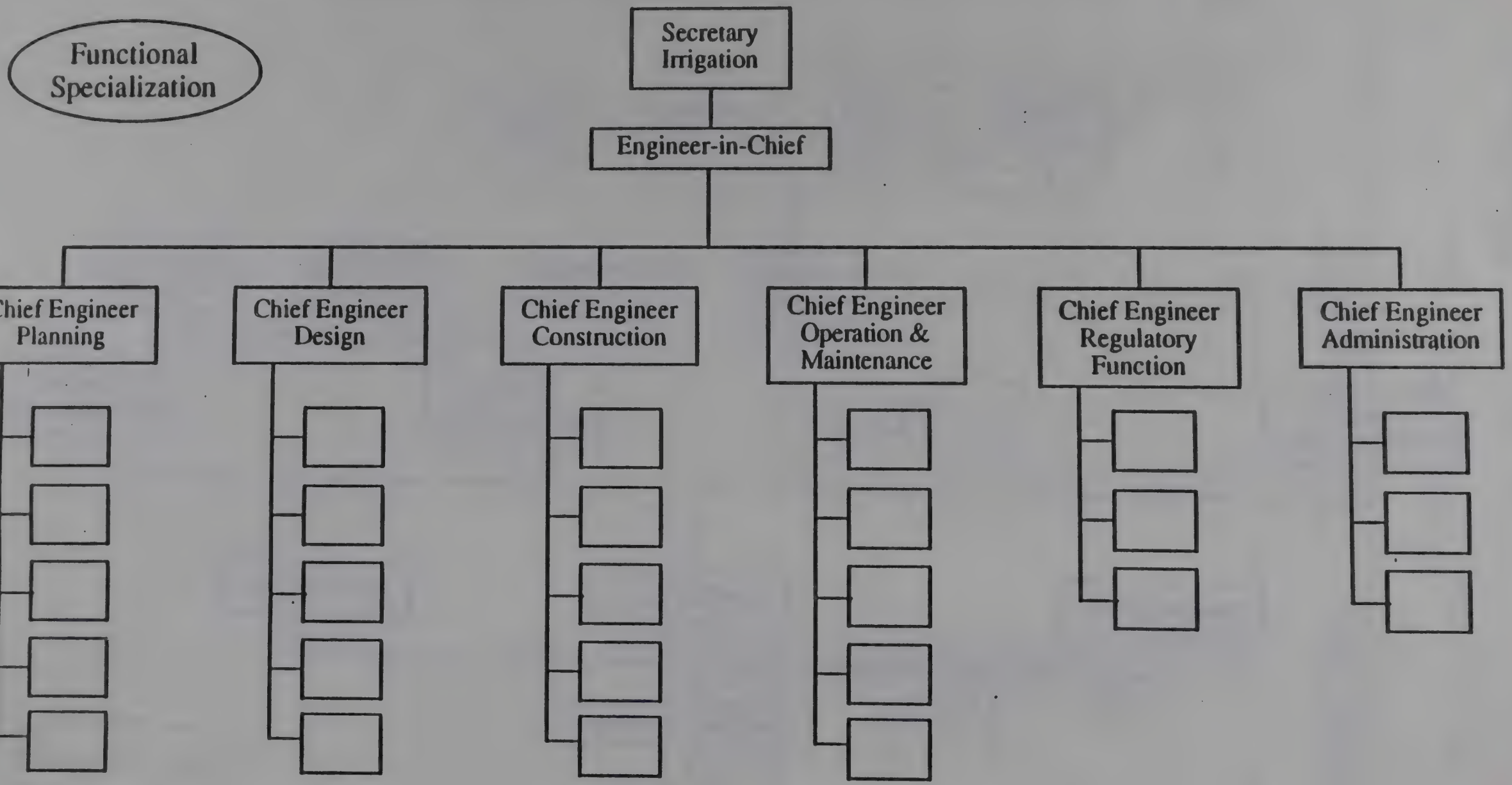
IRRIGATION DEPARTMENT RESTRUCTURING TO PROMOTE FUNCTIONAL SPECIALIZATION

A. TYPICAL EXISTING STRUCTURE OF AN IRRIGATION DEPARTMENT



Annex Figure 7.3
Page 1 of 2

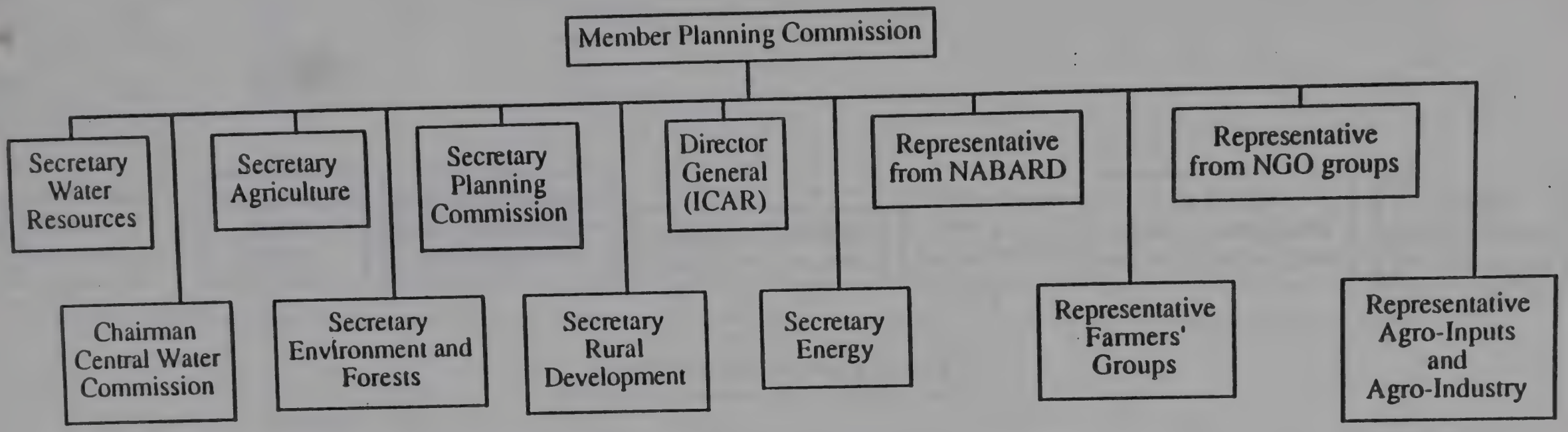
B. ORGANIGRAM OF A RESTRUCTURED IRRIGATION DEPARTMENT *



* Illustrative. Training, project preparation, monitoring and evaluation and cost-accounting functions also need incorporating.

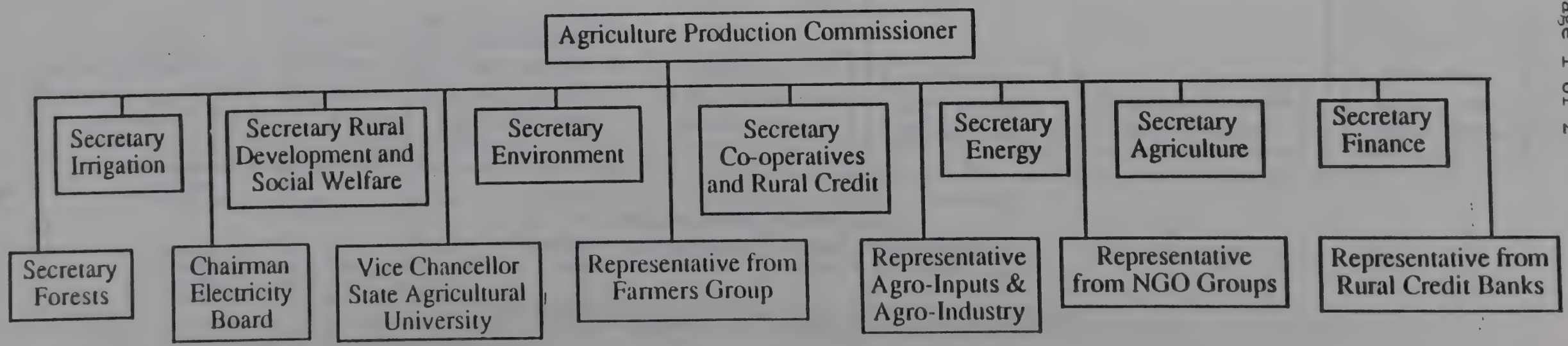
PROPOSED INSTITUTIONAL LINKAGES

A. Coordination Committee at National Level

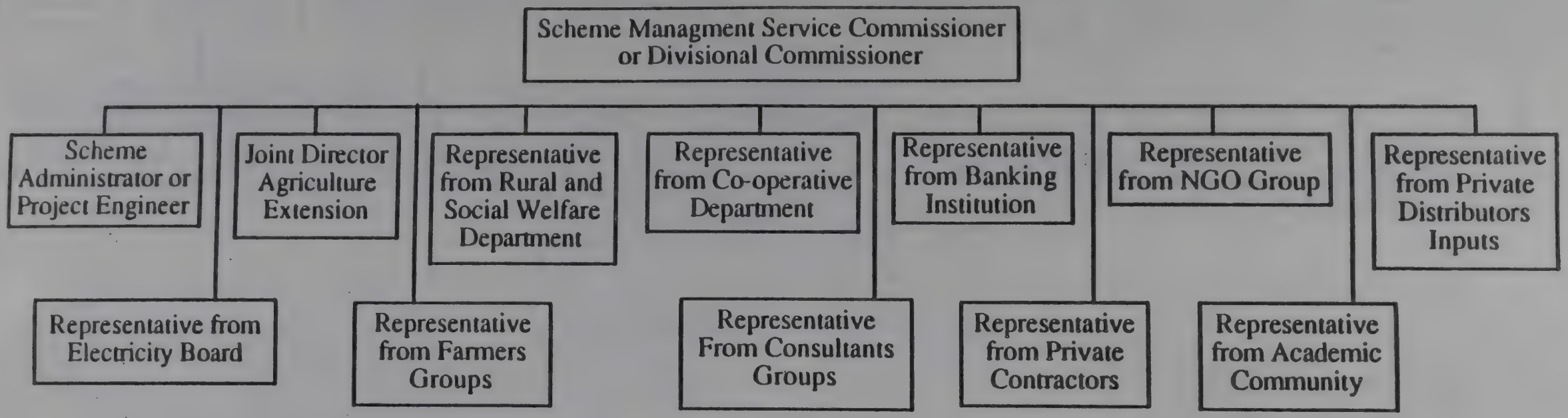


Note: ICAR = Indian Council of Agricultural Research
NABARD = National Bank for Agricultural Refinancing and Development
NGO = Non-Government Organization

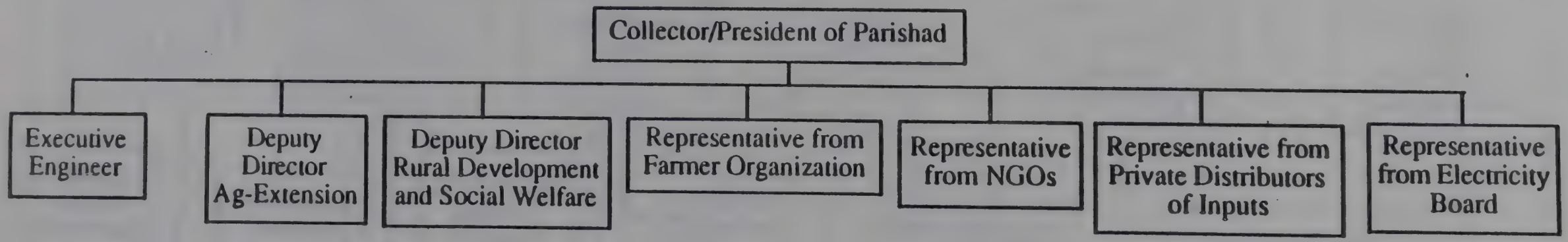
B. Coordination Committee at State Level



C. COORDINATION COMMITTEE AT SCHEME LEVEL


Scheme Managment Service Commissioner or Divisional Commissioner
Scheme Administrator or Project Engineer
Joint Director Agriculture Extension
Representative from Rural and Social Welfare Department
Representative from Co-operative Department
Representative from Banking Institution
Representative from NGO Group
Representative from Private Distributors Inputs
Representative from Electricity Board
Representative from Farmers Groups
Representative From Consultants Groups
Representative from Private Contractors
Representative from Academic Community

D. COORDINATION COMMITTEE AT DISTRICT/JILLA PARISHAD


Collector/President of Parishad
Executive Engineer
Deputy Director Ag-Extension
Deputy Director Rural Development and Social Welfare
Representative from Farmer Organization
Representative from NGOs
Representative from Private Distributors of Inputs
Representative from Electricity Board

BANK/IDA/IFAD LENDING FOR THE IRRIGATION SECTOR IN INDIA: FY1961-FY1990

Bank FY	BOARD APPROVAL				CLOSING DATE				UNDER SUPERVISION AT End-FY	
	Title	State	Cr./Ln. No.	Commitment Amount: $ M	Title	State	Cr/Ln No.	Commitment Amount: $ M	No. of Projects	Commitment Amount: $ M
1961	UP Tubewells	Uttar Pradesh	Cr. 10	6.0	-	-	-	-	4	28.5
	Shetrunji	Gujarat	Cr. 13	4.5						
	Salandi	Orissa	Cr. 14	8.0						
	Punjab Drainage	Punjab	Cr. 15	10.0						
1962	Sone	Bihar	Cr. 21	15.0	-	-	-	-	6	53.5
	Purna	Maharashtra	Cr. 23	10.0						
1963	-	-	-	-	-	-	-	-	6	53.5
1964	-	-	-	-	-	-	-	-	6	53.5
1965	-	-	-	-	UP Tubewells	Uttar Pradesh	Cr. 10		5	53.5
1966	-	-	-	-	Shetrunji	Gujarat	Cr. 13	4.5	4	47.0
1967	-	-	-	-	Punjab Drainage	Punjab	Cr. 15	10.0	3	33.0
1968	-	-	-	-	Sone	Bihar	Cr. 21	15.0	2	18.0
1969	-	-	-	-	Salandi	Orissa	Cr. 14	8.0	-	-
					Purna	Maharashtra	Cr. 23	10.0		
1970	Kadana	Gujarat	Cr. 176	36.5	-	-	-	-	1	36.5
1971	Pochampad	Andhra Pradesh	Cr. 268	40.6	-	-	-	-	2	77.1
1972	-	-	-	-	-	-	-	-	2	77.1
1973	-	-	-	-	-	-	-	-	2	77.1
1974	Rajasthan Canal	Rajasthan	Cr. 502	83.0	-	-	-	-	4	212.1
	Rajasthan Chambal	Rajasthan	Ln. 1011	52.0						
1975	Godavari Barrage	Andhra Pradesh	Cr. 532	45.0	-	-	-	-	6	281.1
	MP Chambal I	Madhya Pradesh	Cr. 562	24.0						
1976	AP Composite I	Andhra Pradesh	Ln. 1251	145.0	-	-	-	-	7	426.1
1977	Periyar Vaigai II	Tamil Nadu	Cr. 720	23.0	Kadana	Gujarat	Cr. 176	36.5	6	372.0
					Pochampad	Andhra Pradesh	Cr. 268	40.6		
1978	Maharashtra I	Maharashtra	Cr. 736	70.0						
	Orissa I	Orissa	Cr. 740	58.0						
	Karnataka I	Karnataka	Cr. 788	126.0						
1979	Gujarat Medium I	Gujarat	Cr. 808	85.0	-	-	-	-	12	951.0
	Haryana I	Haryana	Cr. 843	111.0	-	-	-	-		
	Punjab I	Punjab	Cr. 889	129.0						
1980	Maharashtra II	Maharashtra	Cr. 954	210.0	-	-	-	-	17	1,454.0
	UP Tubewells I	Uttar Pradesh	Cr. 1004	18.0						
	Gujarat Major	Gujarat	Cr. 1011	175.0						
	Rajasthan CAD	Rajasthan	IFAD Ln. 32	50.0						
	Bhima	Maharashtra	IFAD Ln.	50.0						
1981	Mahanadi Barrage	Orissa	Cr. 1078	83.0	Godavari Barrage	Andhra Pradesh	Cr. 532	45.0	19	1,679.5
	MP Medium	Madhya Pradesh	Cr. 1108	140.0	MP Chambal I	Madhya Pradesh	Cr. 562	24.0		
	Karnataka Tanks	Karnataka	Cr. 1116	54.0						
	Sunderbans	West Bengal	IFAD Ln. 49	17.5						

BANK/IDA/IFAD LENDING FOR THE IRRIGATION SECTOR IN INDIA: FY1961-FY1990

Bank FY	BOARD APPROVAL				CLOSING DATE				UNDER SUPERVISION AT End-FY	
	Title	State	Cr./Ln. No.	Commitment Amount: $ M	Title	State	Cr/Ln No.	Commitment Amount: $ M	No. of Projects	Commitment Amount: $ M
1982	MP Major	Madhya Pradesh	Cr. 1170	220.0	Rajasthan Chambal	Rajasthan	Ln. 1011	52.0	20	1,927.8
	Kallada	Kerala	Cr.1264/Ln. 2186	80.3						
1983	MP Chambal II	Madhya Pradesh	Cr. 1288	31.0	Rajasthan Canal	Rajasthan	Cr. 502	83.0	23	2,325.8
	Subernerekha	Bihar	Cr. 1289	127.0	UP Tubewells I	Uttar Pradesh	Cr. 1004	18.0		
	Haryana II	Haryana	Cr. 1319	150.0						
	UP Tubewells II	Uttar Pradesh	Cr.1332/IFAD Ln.124	136.3						
	MAWUP	Maharashtra	Cr.1383/Ln. 2186	54.7						
1984	Orissa II	Orissa	Cr. 1393	105.0	Orissa I	Orissa	Cr. 740	58.0	25	2,602.3
	Periyar Vaigai II	Tamil Nadu	Cr. 1468	17.5	Haryana I	Haryana	Cr. 843	85.0		
	Upper Ganga	Uttar Pradesh	Cr. 1483	125.0						
	Gujarat Medium II	Gujarat	Cr. 1496	172.0						
1985	Sardar Sarovar Dam	Gujarat	Cr. 1552/Ln. 2497	300.0	AP Composite I	Andhra Pradesh	Ln. 1251	145.0	23	2,719.3
	Sardar Sarovar Canal	Gujarat	Cr. 1553	150.0	Periyar Vaigai I	Tamil Nadu	Cr. 720	23.0		
					Maharashtra I	Maharashtra	Cr. 736	70.0		
					Gujarat Medium I	Gujarat	Cr. 808	85.0		
1986	West Bengal Minor	West Bengal	Cr. 1619	99.0	Karnataka I	Karnataka	Cr. 788	126.0	22	2,744.3
	Maharashtra III	Maharashtra	Cr. 1621	160.0	Maharashtra II	Maharashtra	Cr. 954	210.0		
	AP Composite II	Andhra Pradesh	Cr. 1815/Ln. 2662	271.0	Punjab I	Punjab	Cr. 889	129.0		
					Bhima	Maharashtra	IFAD Ln.	50.0		
1987	Bihar Tubewells	Bihar	Cr. 1737	68.0					24	2,926.3
	NWMP I	AP/Karn./Tam. Nadu	Cr. 1770	114.0						
1988	-	-	-	-	MP Medium	Madhya Pradesh	Cr. 1108	140.0	22	2,681.3
					Orissa II	Orissa	Cr. 1393	105.0		
1989	Upper Krishna II	Karnataka	n.a.	325.0	Mahanadi	Orissa	Cr. 1078	83.0	14	2,326.0
					Karnataka Tanks	Karnataka	Cr. 1116	54.0		
					MP Major	Madhya Pradesh	Cr. 1170	220.0		
					Kalada	Kerala	Cr. 1204/Ln. 2186	80.0		
					MP Chambal II	Madhya Pradesh	Cr. 1288	31.0		
					Subernerekha	Bihar	Cr. 1289	127.0		
					Periyar Vaigai II	Tamil Nadu	Cr. 1468	17.5		
					Sunderbans	West Bengal	IFAD Ln. 49	17.5		
					Rajasthan CAD	Rajasthan	IFAD Ln. 32	50.0		
1990	Punjab Irrig. & Drainage	Punjab	Cr. 2076/Ln. 3144	165.0					15	2,491.0
	Total Number of Projects:		IBRD/IDA	46						
			IFAD	3						
	Total of Approved Loans/Credits:		IBRD/IDA	4632.4						
			IFAD	117.5						

INDIA

IRRIGATION SECTOR REVIEW

Irrigation Development Potential in India

Background

1. Physiography and Climate. India can be divided into the following physiographic regions: (a) the Himalayan ranges; (b) the Indo-Gangetic plain; (c) the central highlands; (d) the peninsular plateaus; (e) the Western Ghats and associated coastal strip; and (f) the Eastern Ghats, coastal plains and deltas. The Himalayan ranges extend from Jammu-Kashmir in the northwest to Arunachal Pradesh in the northeast of India, and also occupy most of Nepal, the whole of Bhutan and part of China to the north of India. The highest parts of the ranges carry permanent ice fields which form the sources of large glaciers. This mountainous region is drained by a series of great river systems which make major contributions to the run-off from the Indus basin in the northwest and from the Ganga basin in the central and eastern parts of northern India. The great Indo-Gangetic alluvial plain has been built up by the Indus river system in the west and by the Ganga and its tributaries in the center and east. Encompassing an area of about 650,000 km^2 within India, the great plains extend from the desert of the west to the high rainfall area of West Bengal. The central highlands lie between the Indo-Gangetic plain and the plateaus of the Deccan. They form a block of mountains and hills intersected by valleys which account for about 17% of the total land surface of India. The peninsular plateaus form the largest of the physiographic regions. They are drained mainly by east flowing rivers of which the most important are the Mahanadi, Godavari, Krishna, Pennar and Cauvery. The western edge of the plateau is marked by the Western Ghats which form a rugged escarpment located above a narrow coastal plain. The only major westward flowing rivers which breach the escarpment are the Narmada and Tapi. The Eastern Ghats also form an escarpment along the edge of the Deccan plateau, but this is breached by the eastern flowing drainage systems, the most important of which are noted above. All these great eastern flowing rivers terminate on large deltas, and the remaining coastal plains in the east are generally much wider than the plain below the Western Ghats.

2. The great mountain mass of the Himalayas forms a barrier to cold air intrusion from central Asia and protects the Indo-Gangetic plain from very low temperatures in the winter months. The oceans which flank peninsular India are the source of the moisture-laden winds which reach the whole of India during June-September with the southwest monsoon and the southern end of the peninsular with the northeast monsoon in October-December. However, the great land mass of India has a diversity of climates ranging from continental to oceanic. While extremely low winter temperatures are experienced only in the higher regions of the Himalayas, very high summer temperatures occur in most of India before the onset of the southwest monsoon, except in the vicinity of the coast and in the northern mountains where elevation controls temperature. Mean annual rainfall ranges from less than 100 mm in parts of the Rajasthan desert to more than 4,000 mm in parts of the Western Ghats and in the extreme northeast of the country. The incidence of rainfall is also very seasonal, occurring mainly during the southwest monsoon in most of the country excepting in the south of the peninsular and in the western Himalayas. Average annual rainfall and average June-September rainfalls are compared below for selected areas of the country (Table 1).

Table 1 Comparison of Average Annual Rainfall with June/September Average Rainfall in Selected Areas of India

Area	Average Annual rainfall	Average June-Sept. rainfall	Proportion in June-Sept.	Remarks
	------- mm ------		%	
Jammu-Kashmir	997	458	46	Western Himalayas
Himachal Pradesh	1518	993	65	Western Himalayas
Hills of N.W. Uttar Pradesh	1750	1409	80	West-central Himalayas
Hills of W. Bengal & Sikkin	2779	2172	78	East-central Himalayas
Arunachal Pradesh	2997	2085	70	East-central Himalayas
West Rajasthan	310	275	89	W. Indo-Gangetic Plain
East Rajasthan	700	647	92	W. Indo-Gangetic Plain
Punjab-Haryana	584	465	80	W. Indo-Gangetic Plain
W. Uttar Pradesh	836	726	87	Central Indo-Gangetic Plain
E. Uttar Pradesh	1014	893	88	Central Indo-Gangetic Plain
Bihar Plains	1204	1023	85	E. Indo-Gangetic Plain
W. Bengal Plains	1429	1079	75	E. Indo-Gangetic Plain
W. Madhya Pradesh	1043	945	91	W. Central Highlands
E. Madhya Pradesh	1398	1227	88	Central Highlands
Orissa	1484	1143	77	E. Central Highlands
Saurashtra-Kutch	515	479	93	Very drought prone area
Mainland Gujarat	967	920	95	W. Centr. Highlands & Plateau
Central Maharashtra	940	788	84	Deccan Plateau
Southern Maharashtra	794	660	83	Plat., rain shadow of W. Ghats
Interior Andhra Pradesh	676	367	54	Plat shows eff of NE monsoon
Coastal Andhra Pradesh	1008	572	57	Shows effect of NE monsoon
Coastal Karnataka	3292	2886	88	Central W. Ghats
Interior Karnataka (north)	685	447	65	Plateau rain shadow behind W. Ghats/Some effect of NE monsoon
Interior Karnataka (south)	1271	868	68	Plateau, some effect of NE monsoon
Kerala	2978	1998	67	Southern end of W. Ghats
Tamil Nadu	1007	301	30	Marked effect of NE monsoon

Source: India Meteorological Dept., New Delhi (quoted in CWC, 1988)

3. Temperature conditions are suitable for year-round crop production in the whole of India except at higher elevations in the Himalayas. However, winter temperatures control the southern limits winter wheat production and the northern limits of cold season rice cropping. Nevertheless, the rainfall pattern is such that irrigation is necessary in all of India for the production of high yields from dry season crops and to protect the mainly rainfed crops against drought periods in the wet season. In the arid regions of the northwest of India, irrigation is necessary for cropping in all seasons.

Land Resources

4. The total geographical area of India is about 3.29 M km² of which about 3.04 M km² are accounted for in the latest available land use statistics, the balance representing high mountains, deserts and other inaccessible lands. A breakdown of the reporting area according to the land use classification is shown below (Table 2).

Table 2. Summary of Land Use in India

Land Use Classification	Area (M ha)	% of Total Area
Net sown area	140.72	46
Current Fallow	15.36	5
Fallow other than current fallow	9.55	3
Land under tree crops and groves excluded from net sown	3.39	1
Permanent pastures and other grazing land	11.93	4
Culturable waste	15.74	5
Land put to non-agricultural uses excluding forest	20.41	7
Forest	67.16	22
Barren Lands	20.07	7
Total	304.33	100

Source: Quoted in CWC (1989) based on data from Directorate of Economics, Dept. of Agriculture and Cooperation and MOA.

Constitutional and Legal Aspects of Water Resource Development

5. Under the Indian Constitution, every State Government has power to legislate in respect of water which can be exercised for the whole or any part of the State. The State can exercise its authority over water by undertaking works for irrigation, drainage, flood control, water storage, generation of hydropower, and provision of other water supplies. Thus water and its development is primarily a State subject. The Union has power, to the extent Parliament declares it by law to be expedient in the public interest, to legislate for the regulation and development of inter-state rivers and river basins. Thus the authority of the State Government over water can be exercised within such limitations as may be imposed by law by Parliament, but the Union cannot by virtue of its power acquire the rights of user or of constructing water development works, these rights being vested with the State Governments. The Constitution entrusts to the Union all matters relating to rivers as concern foreign countries.

6. Except in connection with a few specific projects (for example, the Damodar Valley Development), Parliament has not considered it expedient to impose any limitations on the regulation and development of inter-State rivers and river basins. However, Parliament has given authority to the Central Government to set up a River Board for any inter-State river under the River Boards Act of 1956, but the functions of the Boards are entirely advisory and do not in any way restrict or control the powers of State Governments regarding water. The Constitution authorizes Parliament "by law" to provide for the adjudication of any dispute or complaint with respect to the use, distribution or control of water in, any inter-State river or basin. Using this provision of the Constitution, Parliament passed the Inter-State Water Disputes Act of 1956 which sets out the conditions under which a water dispute can arise, and authorizes Central Governments to refer any water dispute (which cannot be settled otherwise) to a legal Tribunal for adjudication.

The findings of the Tribunal are regarded as final.

7. Following the rights laid down by the Constitution, the power to legislate to control groundwater development could be only with the State Governments. To date, only Gujarat State has passed a bill for legislative control of groundwater development through its elected assembly, but the date of effectiveness of the bill has yet to be announced.

Surface Water and Groundwater Resources

8. General. It is estimated by the Central Water Commission (CWC) (1988) that the average annual natural run-off available to India (excluding the islands) is about 1,880 BCM. This converts to a per capita average run-off of about 2,500 m^3/yr as compared with 17,500 m^3/yr in the USSR, 6,500 m^3/yr in Japan and 6,200 m^3/yr in the USA. In addition, the amounts of unit area run-off from the various basins of India vary very widely, reflecting the spatial distribution of annual rainfall. Moreover, the rivers of the country carry about 80% of their flow during the monsoon months of June-September and generally in excess of 90% during the period June-November. Thus, there is a very marked low flow season in December-May, and the rivers draining basins located on the central highlands and plateaus regions, which lack snow melt run-off, typically have extremely low flows by the end of the dry season. The problem of the very wide intra-annual variation of natural flows is compounded by the wide inter-annual variation of run-off. With the existing natural run-off regime, capturing a significant proportion of the run-off for beneficial use demands the creation of a very large volume storage reservoirs in all the basins of the country. It should be noted that the natural run-off estimate provided by the (CWC) is inclusive of groundwater outflow to the surface water drainage systems. This is important because the methodology used by the Central Ground Water Board (CGWB) for evaluating the groundwater resources does not specifically take account of what impact developing the assessed resource would have on surface water flows, particularly in the dry season when effluent groundwater forms the major component of river flows which do not collect snow melt.

9. CWC (1989) estimates the utilizable surface water flow "by structures" as 656 BCM/yr, excluding the waters of the Brahmaputra and Barak (Meghna) basins. The estimate appears to discount water left on the rivers for such uses as navigation and flushing. The estimate of utilizable flow as surface water represents about 51% of the estimated mean annual natural run-off exclusive of that from the Brahmaputra and Barak. About 38% of the estimated utilizable flow as surface water is believed to be in the Ganga basin. The most recent estimate of the utilizable groundwater in India, exclusive of the resources in the Brahmaputra and Barak basins and the islands, is about 450 BCM/yr (CGWB, 1989). Thus, taking the Indian estimates of utilizable surface water and groundwater together, the total utilizable water resource represents about 86% of the estimated mean annual natural run-off of about 1290 BCM from this area. While it is recognized that Indian estimates for "utilization" refer to waters at the diversion point or well head (it is not consumptive use) and, moreover, the inter-relationships between the surface water and groundwater resources are very complicated, nevertheless, such a level of total potential utilization from both sources is very high given the run-off regimes on the river systems. There is a definite problem that surface water and groundwater availabilities are not assessed conjunctively. To quote CWC (1988) - "the resource estimates (surface water and groundwater) have been made independently by the two organizations.[1] In view of this, the inter-action between the two resources and the possible changes in the utilization possible from one source because of the development of the other source may not have been fully considered in the figures." The foregoing

[1] The CWC for surface water and the CGWB for groundwater.

discussion indicates the caution which must be applied when using the utilizable water resource estimates.

10. Assessment of the Water Resources by Basins. The background paper "Assessment of Indian Water Resources and Irrigation Development Potential" provides descriptions of the surface water and groundwater resources and their development in twelve major river basins and six composite river basins [2] where irrigated agriculture forms an important part of the total economy and where water resource availability may become a governing constraint on expansion of irrigation. In this respect, the basins of the Brahmaputra and the Barak (Meghna), in the wet and mountainous northeastern part of India, are omitted. The basins described cover about 83% of the total land surface of India. The results of the analyses are summarized in Table 3. The estimates of utilizable flows of surface water and annually available groundwater are those currently used for planning development in India. It should be noted that both utilizable flows of surface water and available groundwater refer to use of water, do not account for return flows and are therefore considerably larger than consumptive use. Nevertheless, the estimates should be used with caution due to the double accounting of surface water and groundwater (paras 8-9). Moreover, the creation of very large volumes of surface water storage would be needed for effective use of surface water flows (see para 8). Storage of the required magnitude appears to be lacking in some basins, and some potential storages that do exist present difficulties to their creation due to the associated resettlement and environment problems. Figure 1 illustrates the relationship between the live storage created and the proportion of the mean annual natural flow intercepted for use in a hypothetical large basin in a monsoon climate.

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2 Aggregates of the basins of several medium sized rivers.

Salient Features of Indian River Basins

Basin Name	Area in India (Km 2)	Riparian States			Surface Water (BCM)		Reservoir Live Storage (BCM)			Surface Water Irrigation	Groundwater		Future Irrigation Development Options
		Name	% of Basin	% of State	Mean Annual Flow	Utilizable Flow - CWC	Complete	Under Constr'n	Potential		Total Available (BCM)	Utilized 1985 (%)	
Madras Comp.	47,000	Tamil Nadu A. Pradesh Karnataka	20.0 70.0 10.0	10 12 2	4.0	high	2 dams and numerous tanks	?	?	Potential to irrigate about 500,000 ha exists.	?	High	The utilizable surface water is essentially fully committed. Madras water supply to be augmented by transfer of 420 MCM/yr from the Krishna. Some potential for additional groundwater development.
Cauvery	87,900	Tamil Nadu Karnataka Kerala	55.5 41.2 3.3	36 17 7	20.7	19 (this appears to be high as there are no important storages below Meltur about 200 km above the delta)	7.0 in storages larager than 10 MCM	0.3 in storages larger than 10 MCM	0.5	Potential to irrigated 1,020,000 ha has been created in major projects, mainly in Tamil Nadu and Karnataka, and projects to irrigated 420,000 ha are under construction, mainly in Karnataka. There are also large numbers of tank irrigation schemes in both Tamil Nadu and Karnataka.	11.7	55	There is limited potential to expand surface water irrigation in the Tamil Nadu part of the basin, and major investments on improvements to the delta irrigation system must wait the settlement of the Cauvery Water Dispute. Priority investments on surface water development in Karnataka will be on completion of ongoing projects. There is scope for additional development of groundwater, particularly in Karnataka.
W. Ghats Comp.	80,000	Gujarat Maharashtra Goa Karnataka Kerala Tamil Nadu	(4) (20) (4) (30) (38) (4)	(8) (9) (100) (14) (93) (2)	198 (about 658 BCM on major rivers)	36	9.75	10.12	0.58	Potential to irrigated at least 1,000,000 ha has been developed, of which a large proportion is in Kerala.	16	21	Additional development of surface water irrigation may be constrained by limited command area and by lack of reservoir sites. There is scope for additional groundwater development on the coastal plain and in the foothills.
S. Tamil Nadu Comp.	60,000	Tamil Nadu	100	46	17.7	16.7	1.33 in storages larger than 10 MCM	0.8 in storages large than 10 MCM	0.2	Potential to irrigated about 220,000 ha has been created on large schemes. There is also a large number of tank irrigation schemes.	21	60	There is little scope for additional surface water development apart from system operation improvements. There is scope for additional groundwater development.

Salient Features of Indian River Basins

Basin Name	Area in India (Km 2)	Riparian States			Surface Water (BCM)		Reservoir Live Storage (BCM)			Surface Water Irrigation	Groundwater		Future Irrigation Development Options
		Name	% of Basin	% of State	Mean Annual Flow	Utilizable Flow - CWC	Complete	Under Constr'n	Potential		Total Available (BCM)	Utilized 1985 (%)	
East Comp.	50,000	Orissa A. Pradesh	80.0 20.0	26 10	9.3	?	0.68	1.5	(4.7)	Potential to irrigate about 550,000 ha created. Several schemes, mainly in Andhra Pradesh, under construction.	18.9	12	Short to medium term investments in surface water development will be on completion of ongoing schemes, mainly in Andhra Pradesh. Considerable scope for additional groundwater development. Creation of additional storages necessary to firm up surface water supplies.
Godavari	312,800	Maharashtra M. Pradesh A. Pradesh Orissa Karnataka	48.6 20.7 23.8 5.5 1.4	49 15 27 11 2	119	64	18.6 of which 41% in Maha., 18% in AP, 33% in Orissa, 8% in MP.	12.0	2.8	Potential to irrigate 920,000 ha created and projects under construction will irrigate 2,660,000 ha. About 40% of development in AP and most of the balance is in Maharashtra.	42.0	16	In the short-medium term, priority investments in surface water development will be on completion of ongoing schmes. Andhra Pradesh has sanction to transfer water from the Godavari to the head of the Krishna delta. The conceptual plan to transfer 19 BCM/yr of Godavari water (together with 19 BCM/yr of Mahanadi water) will require the creation of large additional storages on the Godavari. There is evident scope for additional groundwater development.
Krishna	258,900	Karnataka Maharashtra A. Pradesh	43.8 26.8 29.4	59 23 27	67.8	85	30.19 of which 39% in AP, 24% in Maha., 37% in Karnataka.	7.14	0.42	Potential to irrigate 1,020,000 ha created and projects under construction will irrigated about 3,580,000 ha. There is also a large number of tank irrigation schemes.	25.0	33	The main future investment for Andhra Pradesh will be on completing the ongoing Somasila project. There is little scope for additional surface water development in this basin based on locally generated water supply, but a water transfer from Godavari to the Krishna delta will release water for that State's use in the upper basin or for transfer to the Pennar basin. There is scope for additional groundwater development.
Pennar	55,200	A. Pradesh Karnataka	88.0 12.0	18 3	6.9	6.9 (high util. reflects a very large number of tanks and long rainy season).	0.36 in storages larger than 10 MCM.	2.15 in storages large than 10 MCM.	0	Potential to irrigate 20,000 ha created by large projects and projects under construction will irrigate 40,000 ha. There is also a large number of tank irrigation schemes.	4.2	33	The main future investment for Andhra Pradesh will be on completing the ongoing Somasila project. There is little scope for additional surface water development in this basin based on locally generated water supply, but a water transfer from Godavari via Krishna could lead to expansion or intensification of irrigation. There is scope for additional groundwater development.

Salient Features of Indian River Basins

Basin Name	Area in India (Km 2)	Riparian States			Surface Water (BCM)		Reservoir Live Storage (BCM)			Surface Water Irrigation	Groundwater		Future Irrigation Development Options
		Name	% of Basin	% of State	Mean Annual Flow	Utilizable Flow - CWC	Complete	Under Constr'n	Potential		Total Available (BCM)	Utilized 1985 (%)	
Tapi	65,150	Maharashtra M. Pradesh Gujarat	79.0 15.0 6.0	17 2 2	18	14.5	8.39	0.69	0.17	About 314,000 ha in Gujarat and about 110,000 ha in MP and Maharashtra. Projects to serve about 80,000 ha under construction in MP and Maharashtra.	9.4	23	Additional drainage required in Ukai-Kakrapar project in Gujarat. Completion of ongoing projects is the priority in MP and Maharashtra where lack of storage limits additional development. Considerable scope for groundwater development.
Suber-narekha	19,300	Bihar W. Bengal Orissa	71.0 18.0 11.0	8 4 1	10.75	6.8	0.32	3.07	1.6	About 54,000 ha in Bihar and Orissa completed. Projects to irrigate CCAs of 160,000 ha in Bihar initiated, and 90,000 ha in Orissa and 5,000 ha in W. Bengal are planned.	2.0	6	Priority investment will be for completion of the Subernarekha River Development under the Tripartite agreement between Bihar, Orissa and W. Bengal. Scope for groundwater development but constrained by low investment capacity of farmers. Significant demand for M&I water from this basin.
Brah-mani-Baitarani	51,900	Orissa Bihar M. Pradesh	67.0 30.5 2.5	22 9 <1	36.2	18.3	1.09	3.3	6.5	Potential to irrigate 150,000 ha completed Projects to irrigate 460,000 ha are under construction. Most of the development is in Orissa.	5.4	4	Considerable scope for additional surface water development through storages. Short to medium term investments in surface water development will be for completion of ongoing projects in Orissa. Scope for groundwater development but constrained by low invesment capacity of farmers.
Maha-nadi	141,600	M. Pradesh Orissa Bihar Maharashtra	53.0 46.5 0.6 0.1	17 42 <1 <1	66.9	50 (would require large additional storages)	8.62 (of which 5.8 BCM at Hirakud)	4.96	11.7	Potential to irrigate 1,010,000 ha created and projects under construction will irrigate an additional 560,000 ha, mainly in Madhya Pradesh.	23.7	5	Priority investment in MP is to complete ongoing works. Drainage works required in Hirakud command in Orissa. Prime requirements for Mahanadi delta system improvements are flood control and drainage, and construction of Manibhadra dam would be important for the former if resettlement problem can be resolved. Conceptual plan for transfer of up to 19 BCM/yr to southern basins via Godavari is dependent on creation of very large additional storages. Scope for groundwater development but constrained by low investment capacity of farmers.

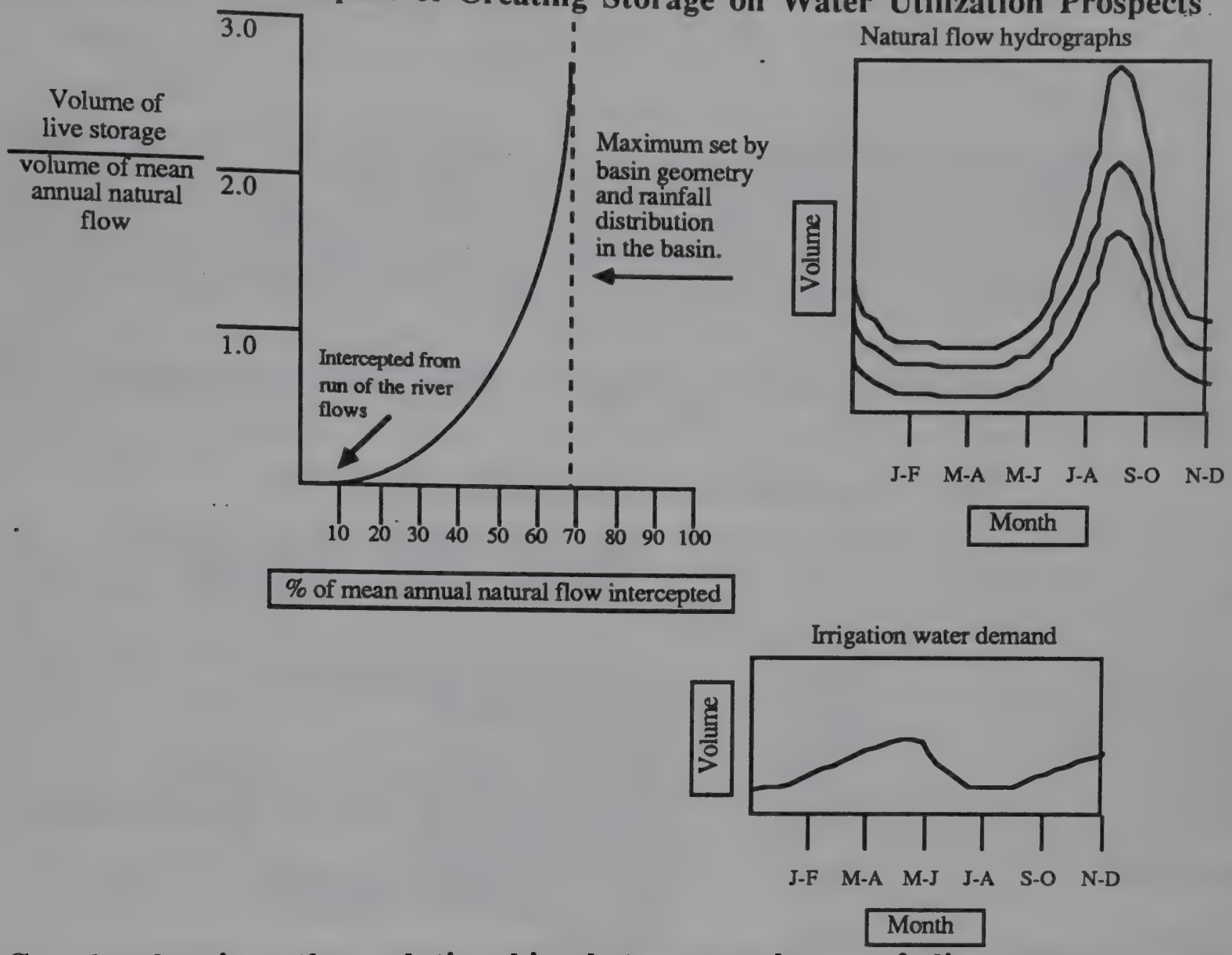
Salient Features of Indian River Basins

Basin Name	Area in India (Km 2)	Riparian States			Surface Water (BCM)		Reservoir Live Storage (BCM)			Surface Water Irrigation	Groundwater		Future Irrigation Development Options
		Name	% of Basin	% of State	Mean Annual Flow	Utilizable Flow - CWC	Complete	Under Constr'n	Potential		Total Available (BCM)	Utilized 1985 (%)	
Saur-ashtra Comp.	60,000	Gujarat	100	31	2.1	?	2.0	-	-	About 242,000 ha of CCA on numerous public schemes of various sizes.	(5)	High	Locally generated sources of surface water almost fully developed. Investments in improvements to existing schemes and on tidal regulators, bandharas and small check structures on minor streams. Major investment in irrigation will occur when Narmada waters reach the area. Limited potential for groundwater development at present but recharge will be enhanced by Narmada water. Domestic water supplies have high priority.
Cambay Comp.	56,500	Gujarat Rajasthan M. Pradesh	60.0 39.0 1.0	17 5 <1	15.64of which 3.81 on the Sabarmati and 11.83 on Mahi.	5.03 of which 1.93 on the Sabarmati and 3.1 on Mahi	3.29 1.09 - Sabarmati 2.2 - Mahi	2.84 0.33 - Sabarmati 2.51 - Mahi	2.5 on Mahi	478,000 ha, mainly in Gujarat, on Mahi; 160,000 ha, all in Gujarat, on Sabarmati	6.9	32	Further development on Sabarmati limited by lack of storages. Additional potential storage on Mahi in Rajasthan but reaching potential command area requires agreement with Gujarat to build Kadana high level canal. Major investment when Narmada transfer waters reach the area in Gujarat. Drainage required in Mahi command area. Considerable potential for additional groundwater development.
Narmada	98,800	M. Pradesh Gujarat Maharashtra	87.0 11.5 1.5	19 6 <1	40.95	34.5	5.72	15.54	0.46	About 370,000 ha of irrigation completed, all in M. Pradesh	12.0	16	Planned developments could increase the surface water irrigated area in Madhya Pradesh part of basin to 2.8 M ha and in Gujarat would irrigate 1.9 M ha, mainly by transfers to the Cambay composite, Saurashtra composite and Kutch composite basin. Small developments are also planned in Maharashtra and Rajasthan based on Narmada water. The Sardar Sarovar project will be the main investment in Gujarat and the Indira Sagar-Omkareshwar projects will be important investments in M. Pradesh in the short-medium term. Conjunctive use of groundwater is planned in the basin.

Salient Features of Indian River Basins

Basin Name	Area in India (Km 2)	Riparian States			Surface Water (BCM)		Reservoir Live Storage (BCM)			Surface Water Irrigation	Groundwater		Future Irrigation Development Options
		Name	% of Basin	% of State	Mean Annual Flow	Utilizable Flow - CWC	Complete	Under Constr'n	Potential		Total Available (BCM)	Utilized 1985 (%)	
Indus	321,000	Jammu - Kashmir Himachal P. Punjab Haryana Rajasthan	52.0 14.0 13.0 3.0 18.0	87 92 100 22 20	73 of which 40.5 on Treaty rivers at rim stations	46.0	14.5 of which 6.86 at Bhakra and 7.12 at Pong	2.34 at Thein	-	2.996 M ha in Punjab; 2.856 M ha in Haryana; 1.55 M ha planned in Rajasthan of which 0.645 M ha completed; small schemes in Jammu-Kashmir and Himachal Pradesh.	25.5 available indicated in this column do not account for the impact of such development on surface water flows.	79	Development in Jammu-Kashmir and Himachal Pradesh limited under Indus Basin Treaty and by terrain. Punjab surface water almost entirely developed - future investments on system modernization and on drainage in southwest Punjab. Haryana will have additional surface water when Thein dam completed - future investments on system modernization and on drainage. Surface water development in Rajasthan mainly on completion of Indira Gandhi canal system and on drainage systems. Limited groundwater development possible in Haryana and Rajasthan.
Ganga	861,500	Rajasthan Haryana Delhi UT Himachal P Uttar Prad. Madhya Pr Bihar West Beng	13.0 4.0 0.2 0.5 34.2 23.1 16.7 8.3	33 78 100 8 100 45 83 81	502 of which 441 to Farakka	250 (this appears an over-estimate with the identified storages)	34.8 of which 30.8 above Farakka	14.8	6.5 in India (up to 76 in Nepal)	13.0 M ha on public schemes of which about 51% in Uttar Pradesh, 25% in Bihar, 9% in W. Bengal, 7% in Haryana, 4% in Madhya Pradesh and 3% in Rajasthan. About 3.0 M ha on small private schemes (tanks, river lifts, etc.)	175	26	Surface water resources in dry season essentially fully developed with existing storages. Creation of additional storages and completion of dams under construction essential for major expansion of surface water irrigation. Investments for improving the operational characteristics of irrigation systems are justified. Investments in drainage and flood control are necessary. Large potential for additional groundwater development; particularly in eastern UP, Bihar and West Bengal on the plains, and in MP on the highlands and plateau region, but possible impact on river base flows must be recognized.
Kutch Comp.	87,000 excluding Rams	Rajasthan Gujarat	79.0 21.0	20 9	13	?	0.6	?	?	About 100,000 ha, including transfer from Sabarmati via Dharoi dam. Mainly on public schemes and mainly in Gujarat.	(7)	(40)	Apart from completion of some medium sized schemes in Gujarat, the major future water irrigation investments will be for the development of the Narmada river water from Sardar Sarovar dam in Gujarat. There is scope for additional groundwater development in the basin.

Figure 1: Impact of Creating Storage on Water Utilization Prospects


3.0
2.0
1.0
Volume of live storage / volume of mean annual natural flow
Maximum set by basin geometry and rainfall distribution in the basin.
Intercepted from run of the river flows
10 20 30 40 50 60 70 80 90 100
% of mean annual natural flow intercepted
Natural flow hydrographs
Volume
J-F M-A M-J J-A S-O N-D
Month
Irrigation water demand
Volume
J-F M-A M-J J-A S-O N-D
Month

Graph showing the relationship between volume of live storage and the proportion of the mean annual natural flow intercepted for used in a hypothetical large basin in a monsoon climate.

11. Water Sharing Arrangements. With only two exceptions, the defined basins cover parts of two or more States in India. Two of the basin areas - the Indus and Ganga - have full extent beyond the boundaries of India. At the international level, the sharing of the waters of the Indus basin between India and Pakistan was agreed under the Indus Basin Treaty of 1960. The agreements between India and Nepal cover only parts of the waters of the Ganga system originating in Nepal. A final agreement has yet to be reached between India and Bangladesh on sharing the water of the Ganga during the low flow period. The surface water resources of the Narmada and Krishna basins are divided between the riparian States according to Tribunal awards. The Godavari waters are shared according to State agreement with a Tribunal award permitting Andhra Pradesh to make a water transfer from the Godavari to the Krishna. In other basins, only part of the surface water resource is shared under formal agreements (Ganga, Subernarekha, Tapi and Mahi). The findings of the Ravi-Beas Tribunal in the Indus basin have yet to be finalized. An inter-State dispute between Tamil Nadu, Karnataka and Kerala regarding the waters of the Cauvery has remained unresolved since 1974. Sharing of the water of the Yamuna between Haryana and Uttar Pradesh is still a matter of dispute despite an existing inter-State agreement. None of the existing agreements cover groundwater development and some Tribunal awards specifically make

decisions on groundwater development an individual riparian issue, though effluent flows from this source are major contributors to river discharges in the low flow season in all the basins discussed. All the Tribunal awards are time bound and may be subject to reassessment at a specified future date.

12. The foregoing discussion indicates the difficulty of allocating the water resources between riparian basin states in many of the basins. The methodology applied for assessing groundwater resources and the existing arrangements regarding groundwater development allow estimates of resource availability to be made for any defined area of a State - for example, the area within a basin - but the problem raised by double accounting of surface water and groundwater remains.

13. The distributions of the riparian states within the various basins are summarized below (Table 4).

Table 4 State Areas and their distributions within basins

State	Area (Km2)	Basins within which State is a riparian and percentage of State area covered by Basin
Jammu-Kashmir	222,236	Indus (87), part drains into China (13)
Himachal Pradesh	55,673	Indus (92), Ganga (8)
Punjab	50,362	Indus (100)
Haryana	44,222	Ganga (78), Indus (22), basin divide ill-defined
Rajasthan	342,220	Ganga (33), Indus (20), Kutch (20), Cambay (5), internally drained desert basin (22)
Madhya Pradesh	442,841	Ganga (45), Narmada (19), Mahanadi (17), Godavari (15), Tapi (2), Cambay (<1), Brahmani (<1)
Uttar Pradesh	294,413	Ganga (100)
Bihar	173,876	Ganga (83), Brahmani (9), Subarnarekha (8), Mahanadi (<1)
West Bengal	87,853	Ganga (81), Subarnarekha (4), balance in Brahmaputra (15)
Orissa	155,782	Mahanadi (42), Brahmani (26), East Comp. (18), Godavari (11), Subarnarekha (2)
Gujarat	195,980	Saurashtra (31), Cambay (17), Kutch (9), Narmada (6), Tapi (2), excludes area of Ranns
Maharashtra	307,762	Godavari (49), Krishna (23), Tapi (17), W. Ghats (9), Narmada (<1), Mahanadi (<1)
Andhra Pradesh	276,800	Godavari (27), Krishna (27), Pennar (18), Madras Comp. (12), East. Comp. (10)
Karnataka	191,770	Krishna (59), Cauvery (17), Pennar (12), W. Ghats (10), Godavari (2), Madras Comp. (2)
Tamil Nadu	130,070	S. Tamil Nadu Comp. (46), Cauvery (36), Madras Comp. (10), W. Ghats (4)
Kerala	38,860	W. Ghats (98), Cauvery (2)

Note: The figures in brackets indicate the percentage of the area of the State located within the basin.

Water Requirements for Various Uses

14. General. Irrigation is by far the greatest user and consumer of the water resources in all the basins discussed, and this situation will continue at the basin level for the foreseeable future. Nevertheless, provision of domestic water supplies for urban and rural populations and assuring drinking water supplies for livestock are given first priority under the National Water Policy (MOWR of GOI, 1987). This document also recognizes the water needs of hydropower, industry, thermal power and navigation. The need to maintain minimum flows on rivers for flushing pollutants and other environmental reasons, including fisheries, must also be recognized. The National Water Policy gives irrigation second priority in water allocations, but allows that this prioritization might be modified in particular regions with reference to area specific considerations. In this regard, heavy industry and thermal generation may be locally concentrated, as in the coalfield area, and have specific high water demands. Moreover, many of the cities have developed concentrations of industry, the water demands of which are often provided through the city water supply.

15. Irrigation. In an assessment of the water resources of India, CWC (1988) remarks that about 85% of the present water use (from surface water and groundwater) is for agriculture. The same publication estimated that, in 1985, irrigation water use country wide was about 470 BCM, of which 320 BCM was from surface water and 150 BCM was from groundwater. It also forecast a requirement for irrigation use of 630 BCM in the year 2,000 (420 BCM from surface water and 210 BCM from groundwater), and anticipated that irrigation use demand could rise to 770 BCM in 2025 with 520 BCM from surface water and 260 BCM from groundwater. The forecast irrigation use requirements for the years 2000 and 2025 represent about 34% and 41% respectively of the estimated mean annual natural runoff of 1880 BCM from the land surface of India (para 8). However, it should be noted that irrigation use is measured at the primary diversion point on a river or at the well head, and a large proportion (up to 50% or more) will be recycled back to the surface water or groundwater systems of the basins from which it is withdrawn.

16. Community Water Supply Requirements. In the context of the International Drinking Water and Sanitation Decade, the GOI launched a decade program in April 1981 which aimed to achieve 100% protected water supply facilities in urban and rural areas, 80% sanitation facilities in urban areas, and 25% sanitation facilities in rural areas in 1991. At the start of the decade, about 72% of the urban population and 31% of the rural population had protected water supply facilities, but sanitation coverage was only 25% in urban areas and 0.5% in rural areas. The program has been implemented more slowly than was anticipated, and a mid-decade review conference in October 1985, recognizing the financial constraints on the sector under the Seventh Five Year Plan (1985–90), recommended that the decade targets should be scaled down to providing 90% of urban populations and 85% of rural populations with protected water supplies, and 50% of urban populations and 5% of rural populations with sanitation.

17. The estimated annual water requirement for domestic use and livestock watering was 16.7 BCM in 1985, and was forecast to reach 28.7 BCM by the year 2000 and 40 BCM by 2025 (figures quoted in CWC, 1988)[3]. It is self-evident that domestic and cattle watering supplies must be very secure and of good quality. While the total requirement for domestic use is not high in terms of India's total water resources, localized area of high demand can create supply problems. Such problems are already presented by the urban conurbations of Delhi, Calcutta, Madras and

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3 The forecast water demands for community water supplies appear to have been based on relatively low assumptions for per capita demands, and may prove to have been under-estimated by about 100%.

Bombay and some of the other larger cities, particularly those of peninsular India. Provision of domestic and cattle water supplies presents problems on a more regional scale in the drought prone areas of India. Whole regions may become very water short for extended periods, as was the case in large areas of Gujarat and Rajasthan (and elsewhere in west-central India) during the prolonged drought of 1984-87 when a sequence of below average monsoon rainfalls was experienced. In that period in Saurashtra, reservoir supplies were withdrawn from irrigation (some permanently) to provide domestic water to the population and to serve the cattle. It has been estimated that Gujarat alone spent about US$1,000 M for the provision of emergency water supplies to the population during the drought.

18. Waste water disposal can be a problem, particularly from urban centers, many of which have inadequate sewage treatment plants , and waters with high BOD and/or coli contents are turned out into the rivers. The problem is compounded by industrial waste water generated in the municipalities which is disposed of through their waste water systems. While urban waste waters are not the only potential sources of pollution to river waters (industrial waste from large plants with captive water supplies can threaten the beneficial use of water bodies to which it is discharged), community waste waters from urban centers are generally more ubiquitous, and the situation demands allocation of part of the river flows for their dilution and to permit natural purification. An often less immediately evident but potentially more serious problem is presented by waste water (from any source) which is disposed of, advertently or inadvertently, to the groundwater systems where it becomes a source of pollution. There may be no practicable near term solution to this problem.

19. Hydropower. The total installed capacity at hydropower plants in India is now about 15,600 MW, which represents about 33% of the total installed generating capacity at thermal, nuclear and hydel plants. However, the proportion of energy generated by the hydropower plants is much lower than 33% of total energy generation because hydropower units generally have much lower load factors than thermal and nuclear units. The total quantity of water which passed through the turbines of the then installed hydropower facilities in 1979-80 through 1986-87 has been estimated by the Central Electricity Authority (CEA) as 1745 BCM, which produces an annual average of about 249 BCM or about 13% of the CWC (1988) estimate of the mean annual natural run-off available to India of 1,880 BCM (para 8). The breakdown of the water passed through the turbines in the stated period is given below by regions of India (Table 5).

Table 5. Volumes of Water Passed through Hydro-electric Turbines in Indian Region in 1979/1980 - 1986/87

Region	Volumes through turbines in 1979/80 - 1986/87 (BCM)
Northern	929
Western	157
Southern	562
Eastern	78
North-eastern	19
Total	1745

Source: CEA data quoted by CWC (1988)

20. A recent study by CEA (1989) estimates that there is potential for installation of a total of about 140,000 MW of installed capacity in economically viable hydropower facilities in India. This would be about nine times the presently installed capacity (para 19). Of this total, about 75% would be on Himalayan rivers feeding to the Indus, Ganga and Brahmaputra basins. About 40% of the installed capacity would be on run-of-the-river schemes and the balance would be associated with reservoir storage.

21. Hydro-electric plants have well known advantages. The source of power generation is renewable and pollution-free. O&M costs are low compared with thermal plants, and the units are easy to operate for meeting energy demand peaks. The actual consumptive use of water is only evaporation from reservoirs, but optimum facility operation requirements for water releases may often be in conflict with such demands as irrigation and flood control with reservoir based facilities.

22. Industrial and Thermal Power Uses. No precise estimate of the water demand for industry has, as yet, been developed for India. High water use requirements are presented by such industries as the mining sector, the basic metal industry (both steel and non-ferrous metals), the chemical industry including fertilizers, petro-chemicals, paper, textiles, and cement. While the consumptive use of such industries may be low, some of them present water pollution problems (para 18). In many cases, such industries have developed their own direct sources of water supply. Light industries, demanding relatively small water supplies and located in urban centers, often take water from the municipal supply. The CWC (1988) very roughly estimates that total industrial water use may have reached 14 BCM in 1989-90 and, due to the foreseen urbanization of population with associated industrial development, the water requirement for industry may reach 120 BCM in 2025. Some conflicts between heavy industry and irrigation are already developing, as for example, in the Bihar part of the Subarnarekha basin.

23. Thermal plants use water for cooling in the condensers, generators and transformers. With the typical load factors in India, the circulating water requirement is in the range of 140-170 m^3/h per megawatt of installed capacity. Most Indian thermal plants operate with recycled water, and in such situations, the water consumption averages about 100,000 m^3/yr per megawatt of installed capacity. The CEA estimated the total water consumption at thermal plants in India in 1987 as 2.7 BCM (figure quoted in CWC, 1988).

24. Navigation and River Flushing. While the importance of river transport is recognized in India, and some major waterways have been identified for declaration as National Waterways [4], the amounts of water required for such use on the rivers remain unquantified. The requirement to maintain minimum flows on rivers for flushing pollutants, fisheries and other environmental reasons is self-evident, but the demands are also largely unquantified. The great Farakka barrage was built on the Ganga to ensure dry season flushing water in the Bhagirathi to prevent silting of Calcutta port. The original design envisaged a diversion capacity at the barrage of about 2000 m^3/sec, but the structure was eventually constructed to divert about 1140 m^3sec. The discharges now reaching Farakka in the low flow season (January to May) are often insufficient to allow the design capacity diversion while leaving an acceptable flow on the river for Bangladesh.

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[4] Ganga-Bhagirathi-Hoogli; Brahmaputra; Mahanadi; Godavari; Narmada; Sunderbans area; Krishna; and Tapi.

25. Summary of Future Water Demands for Various Uses. The foregoing discussion (para 14-24) gives the best available estimates of long term demands for water use by the major sectors of the Indian economy, apart from water which must be left on the rivers for navigation, flushing and to maintain fisheries. The volumes of future usage together with rough estimates of water consumed and return flows are summarized below by major users of water (Table 6).

Table 6. Long Term Demands and Consumptions of Water by Various Sectors in India

Sector	Forecast year	Forecast demand (BCM/yr)	% of total demand	Return Flow %	Return Flow Volume (BCM)	Net demand (BCM/yr)	% of total net demand
Irrigation	2025	770	83	50	385	385	91
Community	2025	40	4	70	28	12	3
Industry	2025	120	13	80	96	24	6
		930	100		509	421	100

Irrigation Development and Future Development Potential

26. General. The present development of irrigation and the general scope for further irrigation development, with indicators of what the development priorities could be, are presented by basins in the background report "Assessment of Indian Water Resources and Irrigation Development Potential" and summarized in Table 3. With the exceptions of Punjab and Uttar Pradesh (which lie entirely with the Indus and Ganga basins respectively), all the States within the area covered by the report[5] have riparian areas within two or more basins (see Table 4). However, the entire agriculturally productive area of Jammu and Kashmir lies within the Indus basin.

27. The growth of India's agricultural development from 1951/52 to 1984/85 and the part played by irrigation in that development are illustrated by the data presented below (Table 7).

Table 7 Growth of Indian Agricultural and Irrigation Development (1951/52 - 1984/85)

	1951/52	1965/66	1970/71	1984/85
	---------- M ha ----------			
Net cropped area	119.4	136.2	140.3	140.7
Gross cropped area	133.2	155.3	165.8	175.9
Area cropped more than once	13.8	19.1	25.5	35.2
Net irrigated area	21.0	26.4	31.1	41.8
Gross irrigated area	23.2	30.9	38.2	54.1
Area irrigation more than once	2.2	4.5	7.1	12.3

Source: Directorate of Economics and Statistics, Ministry of Agriculture, GOI.

[5] The States of north-eastern India located within the Brahmaputra and Barak basins are not covered by the Annex and Table 4.

It will be noted that there was a rapid expansion of net cropped area of about 17.5% during the first two decades of the above record, but the net cropped area grew by less than 1% in the last 15 years from 1970/71 to 1984/85. By contrast, the net irrigated area increased by 48% in 1951/52 to 1970/71 and by 99% in 1951/52 to 1984/85. Net irrigated area represented only about 17.6% of net cropped area in 1951/52, but this ratio increased to 35% in 1984/85.

28. Jammu and Kashmir. This state has a total area of 222,236 km^2 of which 87% lies within the Indus basin. The balance drains eastward into China, but is either barren land or icefield in the high Himalayas. The State lies mainly in the catchments of the upper Indus and its Jhelum and Chenab tributaries. The Indus Water Treaty of 1960 between India and Pakistan allocated the waters of these rivers mainly to Pakistan with the provision for India to enjoy continued use and consumption of water for irrigation and other uses that existed at the time of the Treaty, allowing India to develop additional irrigation use up to a specified area (using water from all sources, including groundwater), and permitting India to develop additional M&I water supplies and hydropower facilities that do not involve creation of significant storages. A small part in the south of the State lies within the Ravi river catchment, the waters of which were allocated to India under the Treaty. The conditions of the Treaty and the land conditions in this mainly mountainous State have limited irrigation development. The only new irrigation project of notable size will be constructed in the State when the proposed barrage is built on the Ravi river between Thein dam (under construction) and Madhopur headwork. The main function of the barrage is to divert water to a left bank hydel channel for the benefit of Punjab, but an irrigation channel will take off from the right bank to serve about 50,000 ha in Jammu and Kashmir.

29. Himachal Pradesh. This mainly mountainous State has an area of 55,673 km^2 of which 92% is in the Indus basin and the balance in the Ganga basin. An area in the north of the State lies in the catchment of the Chenab basin, and there the conditions of the Indus Basin Treaty (para 28) as well as land constraints limit the possibility for additional irrigation development. Elsewhere in the State, the surface water resources may be developed according to the State's wishes, if accepted by other basin riparian, but the land constraint remains. There are some broad inter-montane valleys (for example, the Bahl and Nalagarh valleys) where there is potential for additional groundwater development, for which the State does not require agreement with other basin riparians.

30. Punjab. The State has an area of 50,362 km^2 and lies entirely within the Indus basin. It is located mainly on the plain, with only a small extension along the north-eastern edge into the foothills of the Himalayas. Existing surface water command areas total 29,960 km^2 (59% of the State area) and groundwater also serves a significant area of irrigation, either under independent commands or conjunctively with surface water. Though the findings of the Ravi and Beas Water Dispute Tribunal have yet to be finalized, Punjab's present allocation of India's share of the Indus waters is fully committed on existing irrigation schemes. Moreover, the State's groundwater resource is very highly developed or over-developed in almost the entire area. Two fairly large surface water schemes are under construction (Kandi Canal with a CCA of about 50,000 ha and Sutlej-Yamuna Link Lift Canals with a CCA of 130,000 ha). These are not based on new waters but on assessed water savings from canal and channel improvement schemes (lining), from abandoned channels with water rights in urbanized areas, and from groundwater reallocations. Several small dams with small associated command areas are under construction or planned in the Kandi zone foothills. These will intercept some water which was previously wasted in the wet season and will also have flood control benefits. However, the pattern of future public investment in the irrigation systems of Punjab is indicated by the portfolio of project components which

comprises the Bank-assisted Punjab Irrigation and Drainage Project (Cr. 2076/Ln. 3044-IN). In addition to completing the ongoing irrigation expansion projects mentioned above, these are aimed at improving the efficiency and management capability of the existing surface water irrigation system as a whole, and at surface water and groundwater drainage improvements in the southwest of the State where developing waterlogging and secondary soil salinization are progressively causing deterioration of the irrigated lands.

31. Haryana. This State has an area of 44,222 km located entirely on the plains. It covers parts of the Indus and Ganga basins. Though the boundary between the basins within the State is ill–defined, this has limited importance as the waters that the State receives from the Indus and from the Yamuna tributary of the Ganga can be transferred between much of the State's surface water irrigated area through interlinking canal systems. The existing surface water command area covers about 28,560 km^2 (nearly 65% of the State's total area), mainly through gravity canals, but with some lift canal schemes in the south. Present surface water irrigation intensity averages about 60% indicating that the water supplies are spread very thinly. The groundwater resources of the State are highly developed. Haryana will receive additional waters from the Indus river system when the Sutlej-Yamuna Link Canal and Thein dam in Punjab are completed. It may be foreseen that this water will be used to increase irrigation intensities in the existing irrigation system. The State is making large investments on irrigation system improvements, such as canal and channel lining and communications, and these may be expected to continue. Large investments will also be necessary over the period of the next 30 years in surface water and groundwater drainage systems to combat the development of waterlogging and secondary soil salinization, which has already occurred in some areas and could extend into extensive areas of the State in the future unless drainage is provided. There is some potential for additional groundwater development, though the areas in which this can be undertaken must be carefully selected. Potential has been recognized for creation of two relatively large storages on the Yamuna river system (up to 1.24 BCM of live storage at Vyasi site and 0.34 BCM at Lakhwar), in the hills of Uttar Pradesh and above the first major diversion on the Yamuna at Tajewala headworks. Such storage would allow regulation of flows on the river for delivery to Haryana's West Yamuna canal system and for transfer into its Indus basin systems, and to the East Yamuna and Agra canal systems in Uttar Pradesh.

32. Rajasthan. This State covers an area of 342,220 km^2. The northwestern half of the State is arid to semi-arid with mean annual rainfall ranging from <100 mm (near the border with Pakistan) to 500 mm. The State is a riparian in four of the basins described in the background report (para 10), with 33% of its area in the Ganga basin, 20% in the Indus basin, 20% in the Kutch composite basin and 4% in the Cambay composite basin. A large area of desert in the west-central part of the State is internally drained but has insignificant surface water or renewable groundwater resources. The State's Gang canal system, the part of the Bhakra canal system extending into the State, and the Indira Gandhi canal system (under construction) are located within the Indus basin, and are served with water by a sub-basin transfer from headworks on the Sutlej. The only major scheme serving Rajasthan in the Ganga basin is supplied with water from the Chambal river with upstream regulation provided by a cascade of reservoirs, of which Gandhisagar in Madhya Pradesh is the most important. There is very little scope for additional surface water irrigation development in Rajasthan's part of the Kutch composite basin using locally generated sources of water supply, but the State's share of the Narmada river water (620 MCM/annum) will be used in the basin and could support up to 100,000 ha of irrigation. Rajasthan has identified storage of up to 2.5 BCM at two sites (Baneshwar and Anas) on the Mahi river system in the State's part of the Cambay composite basin. However, irrigable command area is lacking in Rajasthan immediately below the sites, and an agreement with Gujarat would be required for the construction of a high level canal from the Kadana dam on the Mahi in Gujarat to

deliver water to a new command area in Rajasthan. Priority investments in surface water irrigation development in Rajasthan appear to be: (a) completion of the Indira Gandhi canal system in the Indus basin; (b) provision of surface water and groundwater drainage systems in the command areas of the Indira Gandhi canal system and the Chambal system to combat waterlogging and secondary soil salinization; and (c) development of the State's share of the Narmada water when the Sardar Sarovar main canal reaches the Rajasthan border. In addition, reaching agreement with Gujarat to allow development of the potential storage on the Mahi river system should be a priority. There is also potential for additional groundwater development, though given the relatively high development of this resource in some parts of the State and the generally low recharge characteristics, this should proceed with caution and selectively.

33. Uttar Pradesh. This State has an area of 294,413 km^2 and lies entirely within the Ganga basin. Most of the State is located on the plain, with a small proportion in the northwest extending into the Himalayas and a strip along the south lying within the Central Highlands region. Development of large public surface water irrigation schemes began in the mid-19th century and the irrigation service area was continuously expanded during the British period. Large schemes were taken up after Independence, particularly to develop the waters of the Himalayan rivers. The total CCA under public systems is now about 6.5 M ha, or about half the total command area served by public surface water systems in the Ganga basin. The surface water resources available to the State with the existing storages are now highly developed during the low flow season. In recent years, Uttar Pradesh has started to construct irrigation systems which can provide only wet season and early dry season water supply to support kharif cropping. Large schemes are now under construction on the upper Ganga river and on the Ghaghara tributary of the Ganga. The groundwater resources on the plains in the western part of the state are fairly highly developed, but there are significant amounts of undeveloped groundwater in the central and eastern parts of the State, particularly in extensive areas which are waterlogged, where such development would not impact negatively on low flows in the rivers.

34. New scenarios for surface water development emerge as new surface water storages are created. Mention has been made of the storage potential which has been identified on the Yamuna river (para 31) which would benefit both Uttar Pradesh and Haryana. The potential for creation of about 7.5 BCM of storage on the Upper Ganga in Uttar Pradesh has been recognized and one dam to impound about 2.5 BCM of live storage is under construction. These storages would benefit Uttar Pradesh's existing irrigation schemes on the upper Ganga system and would provide rabi water supplies to the kharif schemes presently under construction on that system. Potential storages have been identified in Nepal, and arrangements for construction of two large schemes on the Ghaghara river system (Pancheswar Dam with up to 6.8 BCM live storage, and Chisapani Dam to create to up 15 BCM of live storage), which would directly benefit irrigation in Uttar Pradesh, are presently being negotiated between India and Nepal. Major future investments relate to completion of existing dams and creation of new reservoirs which will produce large power benefits and contribute to flood control, in addition to providing additional irrigation supplies.

35. There is scope for investment in improvements to existing surface water irrigation schemes in the State to make better use of the presently available water supply. Given the sizes of the irrigation systems requiring operational improvements and investment budget constraints, low cost solutions based on identifying correct management decisions for proper operation of a system, with hardware inputs restricted to those essential for the operation to be effective, may be the most appropriate. The surface water irrigation schemes also require investments in surface water drainage facilities to remove rainfall surpluses; all the existing schemes lack such facilities. Some irrigated areas require protection against waterlogging, which could be achieved by additional

groundwater development where such supplies are of fresh water, but pipe drainage systems may be required if the underlying groundwater is of poor quality, as in parts of the extreme west of the State. Other areas require flood protection. Future groundwater development should concentrate on known areas of groundwater surplus, particularly the presently waterlogged areas which are underlain by fresh water.

36. Bihar. The State has an area of 173,876 km^2 of which 83% is located in the Ganga basin, 9% in the Brahmani basin, 8% in the Subernarekha basin and less than 1% in the Mahanadi basin. Within the Ganga basin, the State has surface water command areas totalling about 3.25 M ha, mainly within the Gandak, Kosi and Sone irrigation schemes. The Gandak and Kosi schemes are presently based on run-of-the-river supplies, though potential exists for creation of storage above these schemes in Nepal. The Sone scheme has some storage backup from the existing Rihand dam in Uttar Pradesh, and large storages are under construction upstream of Sone barrage, notably at Bansagar in Madhya Pradesh and at North Koel in Bihar. There is no large scale irrigation development in Bihar's part of the Brahmani basin, which lies in the hilly lands of the Central Highlands region. The Subarnarekha River Development Project, undertaken through a tripartite agreement between Bihar, West Bengal and Orissa with Bank-assistance (Cr. --IN), will create about 160,000 ha of CCA for Bihar (with back up storage of about 3.0 BCM in two reservoirs) when it is completed. Most all of Bihar's groundwater development is in the State's part of the Ganga basin.

37. Bihar's future major investments in the creation of new irrigation schemes will be on completion of the North Koel complex in the Ganga basin and the Subarnarekha River Development Project; most of the work to data has been on construction of the dams. The Sone irrigation scheme is a candidate for "modernization", probably in the form of restoring the regulating capacity to properly operate the distribution system. Both the Gandak and Kosi projects suffer from very heavy siltation in the canals during the high flow season, and the provision of desilting facilities on the main canals near the barrages would probably take priority in system improvements in both cases. Investments in surface water drainage and flood protection schemes would also be justified in the State. Groundwater development should be aimed at known areas of groundwater surplus, particularly at known large areas of waterlogging in the State's part of the Ganga basin.

38. West Bengal. The State has an area of 87,853 km^2 of which 81% is located in the Ganga basin, 15% in Brahmaputra basin and 4% in the Subarnarekha basin. The existing public surface water irrigation schemes serve about 1.2 M ha, all located on tributaries of the Baghirathi distributary of the Ganga river. A barrage is under construction on the Teesta tributary of the Brahmaputra which will serve a large irrigation scheme. While presently planned as a run-of-the-river scheme. the irrigation from Teesta barrage could be backed up by construction of a large storage which has been identified on the river system in Sikkim. West Bengal's share of irrigation from the Subarnarekha River Development project is only about 5,000 ha, but the dams being constructed under the project will afford flood moderation benefits to the State. Groundwater development in the State has been constrained by the low investment capacity of the farmers and the high degree of land fragmentation. Future investment priorities for surface water development will be on completion of the Teesta scheme and improvements to existing schemes, for which the Kangsabati project on a Baghirathi distributary of that name, is a prime example. Future groundwater development should be directed towards area of known surpluses, and particularly to waterlogged lands. Investments in flood protection are also necessary.

39. Gujarat. The total area of the State is 195,980 km² and is divided between the Saurashtra composite basin (31%), the Cambay composite basin (17%), the Kutch composite basin (9% excluding the Ranns), the Narmada Basin (6%), and the Tapi basin (2%). The locally generated surface water flows from the Saurashtra peninsular have been almost fully developed and irrigation is in competition with other uses for water during the droughts to which this area is prone. The Kutch composite basin is largely desert or semi-desert and the surface water of the basin which can be mobilized for irrigation is essentially developed. Additional surface water could be captured from the Mahi river in the Cambay composite basin, with possible benefit to Gujarat, if an agreements can be reached between Rajasthan and Gujarat regarding use of the water which could be stored by two potential dams in Rajasthan (see para 32). Gujarat has utilized its water allocation from the Tapi basin in its Ukai-Kakrapar project. The Narmada Water Dispute Tribunal made its award in 1979 and allocated about 32% of the 75% dependable natural flow from the Narmada basin to Gujarat.6/ In the 75% dependable year, the flow was assessed as 34.5 BCM of which 11.1 BCM would be for Gujarat. The project to utilize the Narmada water is now under construction. It involves construction of the Sardar Sarovar dam on the Narmada river to create live storage of 5.8 BCM. In addition to power generation, the dam will serve irrigation water to a planned 1.9 M ha of CCA which will involve transfer of water from the Narmada river into the Cambay, Kutch and Saurashtra composite basins. The dam may be ready to deliver water in about 1995, by which time perhaps 20% of the planned command area may be completed. Thus completion of the Sardar Sarovar project will be Gujarat's most important investment in irrigation for the next two decades. Other possible investments in surface water irrigation include drainage works in the Mahi and Kakrapar command areas. Additional groundwater development is feasible, especially as the command area of the Sardar Sarovar project is expanded, the project having been planned for conjunctive use development of the groundwater and surface water resources.

40. Madhya Pradesh. This is the largest State in India with an area of 442,841 km². It has major riparian interests in five basins and relatively minor interests in two basins as follows:

Basin	% of basin in State	% of State in basin
Ganga	23	45
Narmada	87	19
Mahanadi	53	17
Godavari	21	15
Tapi	15	2
Brahmani	3	<1
Cambay	1	<1

41. Being formed mainly from the amalgamation of a number of Princely States, Madhya Pradesh had only limited irrigation development prior to Independence. The history of irrigation development since Independence indicates an attempt to initiate a large number of projects State-wide which has resulted in a slow rate of completion of most of the projects due to budget constraints. The State has projects under construction in most of the basins in which it has a major riparian interest, including Bansagar dam and irrigation system on the Sone river in the Ganga basin, the Indira Sagar complex of dams and irrigation systems in the Narmada basin,

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6/ 65% was allocated to Madhya Pradesh, 1.6% to Rajasthan and 0.9% to Maharashtra.

Hasdeobango dam and irrigation system in the upper Mahanadi basin, and irrigation systems served from barrages in the upper Tapi basin. There is also a large number of incomplete medium irrigation schemes. It is evident that completion of these works will be priority investments in the short to medium term. This is particularly the case in the Narmada basin where the Tribunal award of 1979 allocated about two thirds of the surface water to Madhya Pradesh (22.5 BCM in the 75% dependable year), and the allocations will be subject to review in 2024. There is scope for significant amounts of additional groundwater development in all the basins in which the State has an interest.

42. Orissa. The State has an area of 155,782 km^2 which is distributed in five basins as follows: Mahanadi - 42%; Brahmani-Baitarani - 26%; the East composite basin - 18%; Godavari – 11%; and Subarnarekha - 2%. Major ongoing works include the Rangali dam and irrigation system and the Anandpur barrage schemes in the Brahmani-Baitarani basin, the Ong dam and irrigation scheme on a Mahanadi tributary, and some smaller works in the East composite basin. The large storage being constructed on the upper Indravati in Orissa's part of the Godavari basin is intended mainly for power generation, but the reservoir will have additional regulation benefits for irrigation in Andhra Pradesh. The State has not yet taken up the works required to develop its share of the Subarnarekha water under the Subarnarekha River Development project (para 36), though Bihar has made fair progress with construction of the dams necessary for the project, which plans to develop 90,000 ha of irrigation in Orissa. There is also a number of medium irrigation schemes with reservoir storage under construction. Completion of the above works will be the priority investments in irrigation development in the State for the short to medium term. Orissa has plans for modernization of the Mahanadi delta irrigation schemes. The first requirements for such development are flood control and drainage, and one solution for the former would include construction of a dam at the Manibhadra site about 50 km above the apex of the delta, though this presents serious resettlement problems. If the dam is constructed to maximize storage, it would be a key element in the conceptual plan to transfer surplus Mahanadi basin water southwards into the water-short basins of southern India. Investments in drainage in the large irrigation system below Hirakud are also necessary. There is large scope for further investment in groundwater development in most of Orissa if a solution for the constraint of the farmer's low investment capacity can be found.

43. Maharashtra. The State has an area of 307,702 km^2 and lies mainly on the Deccan plateau, but also includes part of the Western Ghats region. The State is distributed in six river basins as follows: Godavari - 49%; Krishna - 23%; Tapi - 17%; Western Ghats composite basin - 9%; and Narmada and Mahanadi each less than 1%. Maharashtra has a number of major irrigation projects under construction, mainly in the Godavari and Krishna basins. They include the Jayakwadi, Palkhed Waday, Manjra, Upper Penganga, Lower Penganga, Sapali and Pench schemes in the Godavari basin, and the Bhima, Mula, Chaskaman, Kaner, Warner and Dupdal schemes in the Krishna basin. Most of these irrigation developments are associated with storage dams. The water development in the Western Ghats part of the State has been mainly for power generation, and M&I water for Bombay is an important demand in the vicinity of the city in this region. Maharashtra has the right under an interstate agreement with Madhya Pradesh and Gujarat to develop additional surface water in its part of the Tapi basin, but such development is constrained by lack of suitable storage sites. The State's allocation of Narmada basin water could irrigate up to about 100,000 ha, but is as yet undeveloped. Short to medium term investment in surface water irrigation in Maharashtra will be for completion of ongoing projects. There is also scope for additional groundwater development for irrigation in the State.

44. Andhra Pradesh. Andhra Pradesh has an area of 276,800 km^2 located mainly on the central plateau, but extending into the Eastern Ghats region and including the great deltas of the Godavari and the Krishna rivers. The area is distributed in five river basins as follows: Godavari - 27%; Krishna - 27%; Pennar - 18%; Madras composite basin- 12%; and East composite basin - 10%. A small area between the Krishna and Pennar basins drains independently to the Bay of Bengal. The major ongoing irrigation development in the Godavari basin is the Sriramsagar dam project and the associated Telequ-Ganga canal scheme which will also convey water from the Krishna basin to serve Madras. Smaller projects are under construction in the Pennar basin, including the Somasila dam scheme. Following a Tribunal award (para 11), Andhra Pradesh has sanction to make a basin transfer from the Godavari to the Krishna at a proposed barrage located at Polavaram above the Godavari delta. The canals taken from the barrage will protect a large area of both left and right banks of the Godavari as well as linking to the Krishna above its delta. In addition to increasing the irrigated area in the lower Krishna basin, this transfer will permit release of water previously committed for use on the Krishna delta to be used in the upper Krishna basin. Completion of ongoing and planned projects will be priority future investments for Andhra Pradesh. There is also potential for creation of additional large reservoirs on the Godavari in the State at Inchampalli (just below the upper Godavari - Indravati confluence), and just above the proposed Polavarm barrage site. The development of these reservoirs would be central to the conceptual plan to transfer large perceived surpluses of surface water in the Godavari basins into the water-short basins of southern India. Scope remains for additional groundwater development.

45. Karnataka. The State, with an area of 191,770 km^2, is located within the following basins: Krishna - 59%; Cauvery - 17%; Pennar - 12%; Western Ghats composite basin - 10%; Godavari - <2%; and Madras composite basin - <2%. Karnataka has a number of irrigation schemes under construction in the Krishna basin. These include the Almati project with a dam on the Ghataprabha tributary of the Krishna, part of the very large Tungabhadra schemes, and some small projects in the southern part of the basin. The largest irrigation project which is under construction in the State's part of the Cauvery basin is the Hemavathi scheme. There is little scope for creating additional storages within Karnataka in either the Krishna or the Cauvery basins. Some small schemes are under construction on the coastal plain in the part of the Western Ghats composite basin which is located within the State. There appears to be very limited scope for additional surface water irrigation development in the State's part of the Pennar basin. Thus future investments in surface water irrigation will be on completion of schemes under construction and improvements to enhance the performance of existing schemes. Additional groundwater development can be foreseen in Karnataka.

46. Tamil Nadu. The State has an area of 130,070 km^2 which is distributed in the South Tamil Nadu composite basin (46%), the Cauvery basin (36%), the Madras composite basin (12%), and the Western Ghats composite basin (4%). The surface water resources of the State are very highly developed through a number of large and small dams and a multitude of tanks. Thus, there is very limited scope for capturing additional surface water run-off for irrigation. Future investments will be on improvements to existing schemes, but investments in modernizing the Cauvery delta system must await resolution of the Cauvery water dispute (para 11). The groundwater resources of the State are fairly highly developed, but there is scope for additional development in some areas.

47. Kerala. This small State, with an area of 38,860 km^2 lies entirely within the Western Ghats composite basin. Much of the State is on steep slopes carrying forest or plantation, and the land suitable for irrigation is limited to the narrow coastal plain and the valleys in the adjacent foothills. Moreover, the area has a long rainy season extending from March to December, thus

limiting the need for irrigation. Several small irrigation schemes, based on the run-of-the-river diversions or supported by storage are under construction, an example being the Bank-assisted Kallada Irrigation Project (Cr. 1269/Ln. 2186). Works have also been undertaken to construct tidal regulators, mainly to prevent tidal ingress to creeks during the low flow season to allow cropping on what otherwise would be tidal flats. The State's investments in surface water irrigation development will never be large. But high river discharges associated with large head drops make hydro-power schemes very attractive investments, particularly in situations where high level storage can be created. Groundwater recharge conditions are very good on the coastal alluvial plains, though development of this resources has, to date, been meager, and considerable expansion is feasible at low investment cost.

Estimates of Ultimate Irrigation Potential

48. The Indian definition of irrigation potential is the gross area which theoretically could be irrigated in the year on a scheme. That is the sum of the areas irrigated in all seasons, with an annual or perennial crop included only as its area though its growing covers several seasons in a year. The estimates are usually derived from an assumed design cropping pattern. The figures quoted are not easily related to the cultivated command areas (CCA) because the irrigation intensities necessary to make the conversions are not given. The commonly quoted estimate of the ultimate irrigation potential in India is about 113.5 M ha using water from all sources. The following breakdown of ultimate irrigation potential by States was given by CWC (1981) and appears to have remained unchanged over the past decade (Table 8), though the Seventh Plan indicated that ultimate potential could increase to about 148 M ha if the water provided by inter-basin transfers and increased groundwater usage were fully accounted.

Table 8: Estimates of Ultimate Irrigation Potential by States

State	Major and Medium Schemes	Minor Schemes			Grand Total	% of Total
		Groundwater	Surface Water	Total		
	,000 ha					
Andhra Pradesh	5,000	2,200	2,000	4,200	9,200	8.1
Assam	970	700	1,000	1,700	2,670	2.4
Bihar	6,500	4,000	1,900	5,900	12,400	10.9
Gujarat	3,000	1,500	250	1,750	4,750	4.2
Haryana	3,000	1,500	50	1,550	4,550	4.0
Himachal Pradesh	50	50	235	285	335	0.3
Jammu and Kashmir	250	150	400	550	800	0.7
Karnataka	2,500	1,200	900	2,100	4,600	4.0
Kerala	1,000	300	800	1,100	2,100	1.9
Madhya Pradesh	6,000	3,000	1,200	4,200	10,200	9.0
Maharashtra	4,100	2,000	200	3,200	7,300	6.4
Manipur	135	5	100	105	240	0.2
Meghalaya	20	15	85	100	120	<0.1
Nagaland	10	5	75	80	90	0.1
Orissa	3,600	1,500	800	2,300	5,900	5.2
Punjab	3,000	3,500	50	3,550	6,550	5.8
Rajasthan	2,750	2,000	400	2,400	5,150	4.5
Sikkum	20	2	20	22	42	<0.1
Tamil Nadu	1,500	1,500	900	2,400	3,900	3.4
Tripura	100	15	100	115	215	0.2
Uttar Pradesh	12,500	12,000	1,200	13,200	25,700	22.7
West Bengal	2,310	2,500	1,300	3,800	6,110	5.4
All Union Territories	160	120	130	250	410	0.4
All India	58,475	39,762	15,095	54,857	113,332	100.0
% of Grand Total	51.6	35.1	13.3	48.4	100.0	

Source: CWC, MOI, Govt. of India, 1981.
Note: Major schemes - > 10,000 ha; Medium schemes - 2,000 to 10,000 ha; Minor schemes - < 2,000 ha.

49. The CWC publication states that the above is a broad estimate. The estimates of irrigated area are not clearly related to water availability. They, presumably, were based on the mean annual water assessment's given in the document as all-India totals of 1,760 BCM for surface water and 275 BCM for groundwater, but the proportions of use of these totals for irrigation in the stated areas are not given. It should be noted that current estimates are 1,880 BCM for average annual natural run off (CWC, 1988) and 450 BCM/yr for the utilizable groundwater in India (CG WB, 1989), though the probability of double counting is admitted (see paras 8, 9). CWC (1981) states that "the total (irrigation) potential can increase significantly by optimum development of our river systems by fuller inter-state cooperation and cooperative development of international rivers with neighboring countries." This statement obviously refers to possible basin transfers in India (mainly from Mahanadi and Godavari to the water short southern basins), and the storage of water on the Himalayan rivers in Nepal and, perhaps, the suggested Brahmaputra to Ganga transfer across Bangladesh.

50. The report of the Irrigation Commission (1972) attempted to develop estimates of the ultimate irrigation potential of India. The Commission first approached the States for their estimates of irrigation potential with the standard breakdown into groundwater and surface water schemes. The States' estimates were then reviewed and adjusted as thought necessary by the Commission to provide the following estimates for India:

Scheme type	Irrigation potential (M.ha)
Major and medium	45.5
Minor surface water	14.0
Minor groundwater	22.2
Total	81.7

51. The CWC (1981) estimates show a 28% increase for major and medium schemes, a 5% decrease for minor surface water schemes, and a 58% increase for groundwater schemes. The information provided by the States in 1972 identified the major projects in operation, under construction, and contemplated by name, and indicated the ultimate potential to be created by the projects for a total of about 33 M ha. A review of the projects listed as contemplated shows that all of them by now have been constructed or are under construction, some to much larger potentials than were origanally proposed. The questions are posed whether there is scope for further large-scale expansion of the irrigated area through major schemes and to what extent the future will lie with improvements to and intensification of irrigation within existing schemes, once they are all completed.

Estimates of Irrigation Potential Developed and Utilized

52. India has shown remarkable achievement in the development of its irrigation potential, particularly since Independence. As shown by Table 9, about 60% of the total ultimate potential as assessed under Table 8 had been developed by 1985, representing about 52% of the ultimate potential from major and medium sources and 68% of the ultimate potential from minor sources. The total developed irrigation potential from all sources was about 68 M ha in 1984/85, of which 31 M ha on major and medium schemes and 37 M ha on minor schemes. Punjab and Tamil Nadu had by then achieved development of 86% and 82% respectively at their assessed ultimate potentials, and Haryana (73%), Rajasthan (74%) and Uttar Pradesh (73%) had also achieved high levels of development relative to assessed ultimate potential. Considering the inexactitudes of the ultimate potential estimates, it is evident that some of these States may now be approaching their development limits. This is particularly clear in the cases of Punjab and Tamil Nadu.

Table 9: Irrigation Potential Developed and Utilized (June 1985)

	Major and Medium Schemes			Minor Schemes			Total all Sources		
	Area (000 ha)	% of Ultimate	% Utilized	Area (000 ha)	% of Ultimate	% Utilized	Area (000 ha)	% of Ultimate	% Utilized
Andhra Pradesh	3268	65	92	2340	55	94	5608	61	93
Bihar	2879	44	76	3422	58	92	6301	51	84
Gujarat	1264	42	59	1674	96	96	2938	62	80
Haryana	1929	64	91	1387	90	98	3316	73	94
Karnataka	1269	51	85	1128	54	98	2397	52	91
Madhya Pradesh	1802	30	72	1992	47	94	3794	51	72
Maharashtra	1700	41	49	1997	62	92	3697	51	72
Orissa	1568	44	96	1060	46	92	2628	45	94
Punjab	2462	82	99	3174	89	99	5636	86	99
Rajasthan	1812	66	82	1987	83	97	3799	74	90
Tamil Nadu	1244	83	98	1950	81	99	3194	82	99
Uttar Pradesh	6813	55	81	11990	91	92	18803	73	88
West Bengal	1587	69	93	1712	45	93	3299	54	93
Remaining India	900	33	-	1565	36	-	2465	35	-
Total India	30497	52	83	37378	68	94	67875	60	89

Source: Government of India, 1985.

53. Shortfalls in utilization as reported are due to several factors. There are ambiguities in the definitions of "potential created" and " utilized" and the ways in which these estimates are reported by the various States. The potential created is based on the assumptions of design cropping patterns which may not be realized or chosen by the cultivators, who respond to such influences as risk, profitability, and amount and security of the water supply. Many schemes have been designed on the basis of over-optimistic irrigation system efficiencies, and water supplies at field level have, in practice, proved to be considerably less than were anticipated, with consequent reductions in irrigation intensities. However, the planned cropping derived from the assumed water supplies are retained in the estimates of potential created against which shortfalls in utilization are measured. The estimates of minor irrigation potential created and utilized relate to a very large numbers of small schemes (particularly in respect of private groundwater development). The estimates are therefore derived mainly by the application of regional norms.

Summary of Conclusions on Future Irrigation Development Potentials and Priorities

54. General. The foregoing discussions indicate that while India as a whole has considerable potential for further irrigation development, the options and scopes vary widely between States and regions. It must be recognized that in the case of expanding surface water irrigation development, most of the easier and often most cost-effective options have been taken up. New expansion schemes must contend with increasingly marginal conditions in terms of physical setting and, in some cases, of economic returns.

55. Increasing surface water supplies above what has now been captured is dependent mainly on creation of additional storage, and most of the easier to create reservoir sites in India have been taken up. The remainder usually present difficult inter-State agreement problems and/or large environmental and resettlement constraints. Large investments will continue into the medium-term future on the completion of a very large inventory of surface water schemes which are under construction in many of the States, particularly in some States in the Central Highlands and Plateau Regions. Investments for improving the performances of existing surface water irrigation project will be an important component of future funding, predominantly in the States of the Indo-Gangetic plain and of the east coast deltas. However a careful choice of the degree of modernization will be necessary. This will relate to the importance of competing investment options in irrigation and other developments and individual State budget constraints. While investments in drainage have been lacking in most States (Punjab was an exception in the 1950s), development of drainage systems for surface water irrigated areas may be expected to assume importance in the future. This will be mainly in the form of systems for evacuating surface water surpluses, but provision of both surface and groundwater drainage facilities will be essential for maintaining or reclaiming the agricultural production capacities of large areas under irrigation in northwestern India. Flood control investments are required to protect both irrigated and rainfed lands, particularly on the Gangetic plain and on the east coast deltas. There is considerable scope for additional groundwater development in a number of States, notably those located in the eastern Gangetic Plain, in eastward draining basins extending from the Subernarekha to the Krishna, and in the upper Narmada basin.

56. Demands for water for community water supplies and industrial uses form very small parts of India's overall water budget at the diversion point, and even less in terms of consumptive use (see Table 6). However, community supplies must be given highest priority. Both large urban centers and concentrations of heavy industry can create demands which compete with irrigation, as for example, the Delhi and Madras water supplies and the heavy industrial developments in the Subernarekha basin. Adequate flows must be maintained on the major elements of the river systems for such uses as flushing, navigation, and to maintain fisheries. This is often problematic in the low flow season, and such uses then become competitors with irrigation.

57. Storage Reservoirs. According to CWC (1988), India has created live storage in reservoirs totalling about 143 BCM, has projects under construction to create about 79 BCM of live storage, and has projects under consideration which could create 82 BCM of live storage. The breakdown of these figures by basin, excluding the Brahmaputra and Balak basins is presented in Table 3. It is noteworthy that 56% of the storage that would be created by projects under consideration is located in the Brahmaputra-Barak basins and their main function will be for power generation. Taking the completed, under construction and under consideration storage together, they total only 304 BCM which represents only about 16% of the estimated average annual natural turnoff from India, excluding the islands (para 8). Omitting storage and runoff from the Brahmaputra and Barak basin, the storage created, under construction and under consideration totals about 256.5 BCM which represents only about 20% of the estimated average annual natural run off of 1290 BCM from this part of India. It is evident that this quantity of storage is adequate to capture only a small proportion of the runoff, given the hydrologic regimes on India's rivers.

58. Nevertheless, creation of additional storage is critical to India's water development plans, to further growth of surface water irrigation within the basins, and for implementation of conceptual plans for large-scale inter-basin water transfers. Considering the situation regionally:

(a) there is little scope for creation of additional storage in the Indus basin once Thein dam on the Ravi river is completed;

(b) there is scope in the Ganga basin for creation of at least 6.5 BCM of live storage within India (additional to that in place or under construction) and this should be given high priority, as should reaching agreement with Nepal for creation of storages on the Ganga tributaries in that country for the mutual benefits of the basin's international riparians;

(c) the Subernarekha, Brahmani-Bartarani, Mahanadi and Godavari basins among the river systems draining to the east coast have storage potentials under consideration totalling around 24 BCM which should be given high priority for their irrigation, flood control and power benefits, and in the cases of the Mahanadi and Godavari basins, because the storages are crucial to conceptual plans for water transfers from the potential water surplus basins into the water short basins of southern India;

d) there is little scope for creation of additional storage in the eastward draining basins to the south of the Godavari - the CWC (1988) report identified live storage totalling only about 1.8 BCM as under consideration in this entire area;

(e) the major river systems draining to the west coast - Tapi, Narmada, Mahi, and Sabarmati - and the Saurashtra and Kutch areas offer only limited potential for creation of storage additional to that already in place or under construction.

59. The resettlement and environmental problems of creating large reservoirs are acquiring ever increasing importance in the water development debate. Accepting that a properly financed and equitable resettlement plan for reservoir oustees is an essential component of reservoir project planning, the costs of the exercise can be evaluated and a project should be rejected if the financial, economic and social costs of the implicit resettlement requirements are too high. Measurements of environmental disbenefits and benefits of development of reservoirs and the systems they support are often intangible, but in the Indian context, the impact of not implementing a reservoir supported irrigation project must be measured against the loss of food supply to an under-nourished, already dense and rapidly growing population.

60. Completion of Ongoing Projects. The CWC publication of 1989 which describes the 14 major river basins of India records that major irrigation projects under construction will have irrigation potential totalling about 21.6 M ha when they are completed. About 90% of the potential in incomplete projects is concentrated in five basins, with 14% in the Indus, 36% in the Ganga, 12% in the Godavari, 17% in the Krishna and 11% in the Narmada basins. This does not imply that the total irrigation potential on incomplete projects will appear in future statistics; areas of the projects are already being served and the CWC report does not indicate the degree of incompleteness of the 151 major irrigation projects that are under construction. It is not possible to redistribute the potential to be created by incomplete projects by State from the data available. However, the major parts of incomplete irrigation works are located in Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar, West Bengal, Gujarat, Maharashtra, Andhra Pradesh and Karnataka. It is evident that completion of ongoing works will have an important place in the irrigation investment portfolios of these States in the medium term.

61. Improvements to Existing Surface Water Irrigation Systems. A number of States have made investments in improvements to existing surface water irrigation systems to make better use of the available water supply. The amount of hardware investments in system modernization projects vary widely between States. Punjab and Haryana, recognizing that their surface water supplies are very limited, have invested heavily in canal and watercourse lining programs and, to a lesser extent in improvements to canal regulations structures and communication systems, and such investments will form the major part of the irrigation development in these States in the medium term future.[7] Gujarat has also invested heavily in canal and channel lining on existing facilities, notably in the very water short Saurashtra but also in mainland Gujarat. Several modernization projects in the Plateau Region have involved various degrees of canal and channel lining. However, State budget constraints often dictate that this scale of modernization must proceed relatively slowly, especially when compared to the large area requiring system improvements. Moreover, large scale lining investments may not be economically justified in many irrigation systems and the project level water savings may be questioned when basin level water use efficiencies are already high, when an upstream user's losses are a downstream user's gains, and when surface water losses can often be retrieved easily as groundwater. The concepts developed under the Bank assisted National Water Management Project; which concentrates on identifying the correct management decisions for proper operation of a system with hardware inputs restricted to those essential for the operation to be effective, may be more appropriate for rapid application over large areas, and such improvements involve relatively low investment. However, it is considered that investments in appropriate system improvements to make better use of India's existing surface water irrigation systems will be an important component in the irrigation investment portfolios of most States with large developed irrigation potential in the medium term future.

62. Drainage. The agro-climatic conditions in much of India are such that for high productivity agricultural land use, drainage in addition to irrigation is often required. While large public investments have been made in irrigation since the mid-19th century, only meager investments have been made in drainage. Investments in drainage have now become opportune in view of the rising productivity of the land. The major thrust of the land drainage development in most parts of the country would be on removal of rainfall and run-off surpluses through improved surface water drainage systems. Conditions which would warrant such improvements may be found in parts of most States in areas where lands are naturally imperfectly drained. Land use would be an important factor in the decision to provide drainage improvements, and in this respect, land provided with irrigation facilities would normally have a high priority. A background paper prepared for this sector review[8] indicates that in the range of 5 -10 M ha of land in India could economically justify provision of field and tertiary drainage and that the program could be implemented over 20-25 years with costs in the range of Rs 1500-3000/ha (1990 prices).

63. Drainage and in some places reclamation measures are required to protect the sustainability of surface water irrigated agriculture in areas underlain by saline groundwater in parts of Punjab, Haryana, northern Rajasthan and extreme western Uttar Pradesh. Irrigation induced waterlogging and secondary soil salinization problems in this situation can only be solved satisfactorily by increasing the groundwater drainage capacity artificially to restore the water and salt balances in the

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7 Canal and watercourse lining was a design concept for Rajasthan's Indira Gandhi Canal Project and Karnataka's Upper Krishna Project, and is also included in the designs for new systems based on Narmada waters in Madhya Pradesh and Gujarat.

8 Land Drainage and Reclamation, L.K. Smedema, (Irrigation Sector Review Background Paper, 1990).

affected areas. Installation of pipe drainage systems appears to be the most satisfactory solution. Surface water drainage systems are also generally required in these areas to relieve drainage congestion which has been exacerbated by the high water table reducing the runoff attenuation effects of infiltration. One of the major difficulties to solving the irrigation induced waterlogging problems in northwest India is disposal of the saline effluent. The sector review background paper on drainage (para. 63) estimates the total area that will eventually require groundwater drainage as in the range of 250,000 - 500,000 ha. The cost of drainage treatment is estimated as Rs 20,000 - 25,000/ha exclusive of the additional costs which must be incurred eventually for disposal of the drainage effluent.

64. Groundwater. The most recent estimate of the replenishable groundwater resource of India, exclusive of the resources of the Brahmaputra and Barak basins and the islands, is about 450 BCM/yr. (para. 9). After providing a reserve of about 15% of the replenishable resource for community water supplies and industrial uses, the utilizable groundwater for irrigation is estimated to be about 380 BCM/yr. However, this estimate is made without accounting for the outflows from the groundwater systems to the rivers, which are included in the surface water resource estimates and constitute a large proportion of the natural dry season flows of all the river systems which do not have a snow melt contribution (para 8). Despite this reservation, there can be no doubt that large quantities of groundwater remain to be developed in many of the river basins and States of India. Table 10 summarizes the estimates of replensible groundwater, present utilization and remaining resource for irrigation development in the States with large irrigation development demands.

Table 10: Estimates of Groundwater Availability in States with Large Irrigation Demands

State	Replenishable Groundwater	Provision for Community & Industry	Utilizable for Irrigation	Present net Draft	Balance for Exploitation
Andhra Pradesh	43.4	6.5	36.9	7.4	29.5
Bihar	33.8	5.1	28.7	6.8	21.9
Gujarat	22.6	3.4	19.2	6.4	12.8
Haryana	8.5	1.3	7.2	5.1	2.1
Karnataka	16.2	2.4	13.8	5.0	8.8
Kerala	8.1	1.2	6.9	0.7	6.2
Madhya Pradesh	59.7	8.9	50.8	6.0	44.8
Maharashtra	38.8	6.7	32.1	7.0	25.1
Orissa	23.3	3.5	19.8	1.0	18.8
Punjab	18.0	2.7	15.3	15.2	0.1
Rajasthan	16.2	2.9	13.3	5.0	8.3
Tamil Nadu	30.2	4.6	25.6	12.0	13.6
Uttar Pradesh	80.5	12.1	68.4	25.0	43.4
West Bengal	20.7	3.1	17.6	2.9	14.7

Source: CGWB, 1989.

65. Future groundwater development should be by the private sector. Tubewell facilities will be preferred in the alluvial aquifer areas. However, large areas of India are underlain by hard rocks which generally produce aquifers which normally can be exploited for irrigation only by large diameter hand-dug wells, and the costs of these wells are now fairly high. Private shallow tubewell facilities serving about 4.0 ha cost about RS 7,000 . Hand-dug wells equipped with pumpsets and serving about 2.0 ha cost Rs 35,000 - 45,000. The energy demands for pumping are high, and while most farmers prefer electrical power (which is highly subsidized), the demands of such facilities are critical in many States with limited power development.

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